INSTRUCTION MANUAL

DANA®

PUBLICATION NO. 980474

PRELIMINARY

380B

DIGITAL MULTIMETER

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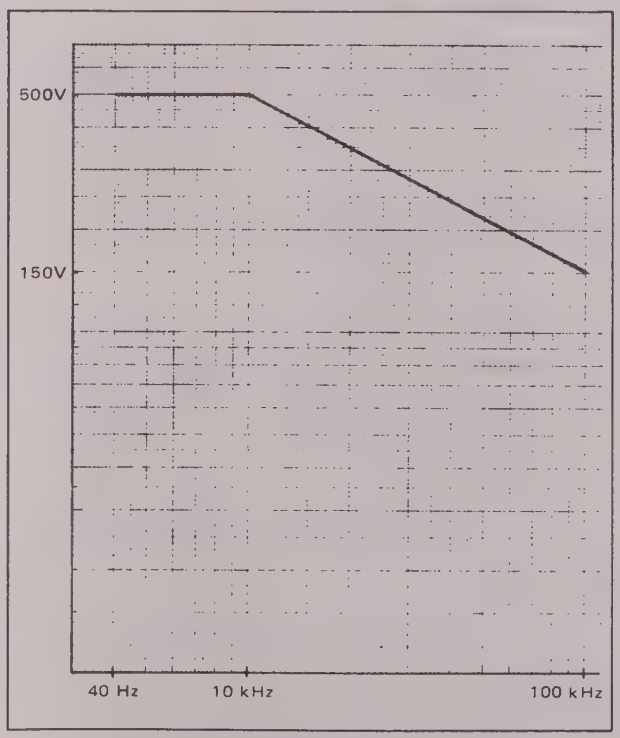
SECTION 1 GENERAL DESCRIPTION

1.1 GENERAL.

1.2 The Dana Model 3800B (figure 1.1) is a compact, highly accurate, three digit instrument featuring auto polarity, 60 dB normal mode noise rejection, 100 dB common mode noise rejection, and 1000 Megohm input resistance on the DC Functions' 2 volt range. Recalibration is required only once a year, with occasional front panel rezeroing of the display.

1.3 The basic instrument exhibits full multimeter capability measuring full scale inputs from 200 millivolts to 1000 volts on five DC ranges, from 2 volts to 500 volts on four AC ranges (see table 1.1), from 200 ohms to 20 megohms on six ohms ranges, and 20 microamps to 2 amps on six DC current ranges.

Table 1.1 - Maximum AC Input



1.4 High reliability is insured by the use of all solid state circuitry throughout the instrument, including the display. Protection from possible introduction of fault voltages is provided through both mechanical and electrical means. Rotary range and function switches prevent ambiguity of selection, and the use of separate input terminals (AC/DC and OHMS/DC current), while routing inputs only when the proper function is selected, reduces the chance of signals reaching the wrong circuitry. The Ohms and DC current functions are protected on all ranges by a 2 amp fuse; the DC volts function is designed to handle inputs of 1000 volts DC or peak AC on all ranges; the AC volts function is designed to handle 600 volts DC or 500 volts AC to 10 kHz, decreasing to 150 volts AC at 100 kHz.

1.5 Available at the time of purchase is the Option 51 Isolated BCD Output (designated 3800B-51). The option is contained within the instrument and supplies positive true binary data for use by a digital recorder or other similar, digitally operated device. Information provided by the option includes the numeric value of the display, overload, decimal position, polarity, and the validity of the data (Print Command).

1.6 Accessories available for the 3800B include:

Model 80	shielded input cable – for use in high noise environments
Model 82	5 KV HV Probe – extends DC measurement to 5 KV
Model 83	50 KV HV Probe – extends DC measurement to 50 KV
Model 84	RF Probe – measures RF frequencies to 200 MHz
Model 86	AC current shunts – measure AC current to 10 kHz
Model 88	Deluxe test leads – include assorted tips
Model 89	Standard test leads – with replaceable tips
Model 60	Rack mounting flanges – mount instrument to 19 inch rack

1.7 MECHANICAL DESCRIPTION.

1.8 The basic DMM is designed as a bench top instrument and comes equipped with a bail handle to simplify carrying. The bail handle rotates 270° and may be used as a "kickstand" for easy viewing and control access. All components of the basic instrument including the power supply are mounted on 3 printed circuit boards and housed in a high-impact plastic case. Access to the interior of the

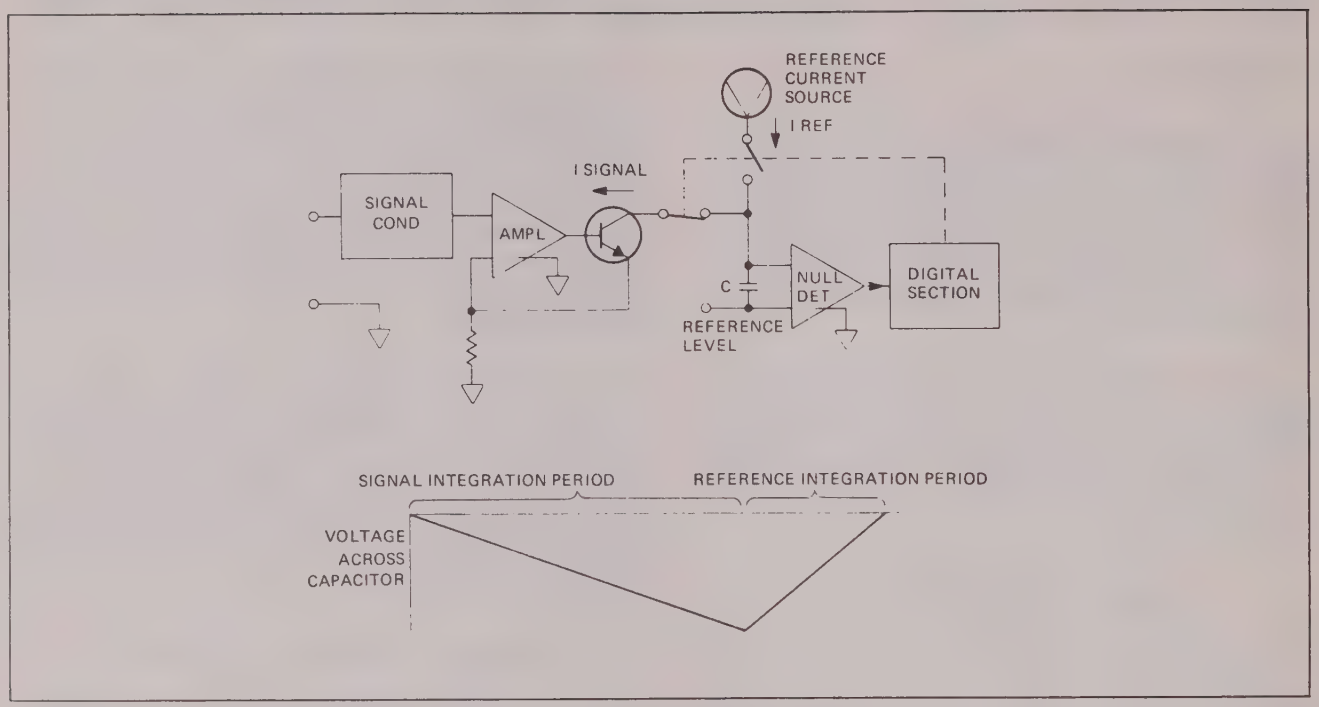


Figure 1.2 - Simplified Block Diagram

instrument for calibration and maintenance is made by removing 2 screws at the top of the back panel, and 2 screws at the top of the side panels.

1.9 ELECTRICAL DESCRIPTION.

1.10 The Series 3800B utilizes the dual-slope integration method of Analog-to-Digital Conversion. This technique minimizes the number of components for increased reliability and lower cost while having inherent advantages of stability and noise rejection. The circuitry that performs the analog-to-digital conversion is shown in the simplified block diagram of figure 1.2. The purpose of the circuitry is to convert the input (a dc level) into a proportional time period. This is done by first converting the input into an equivalent negative current that is applied to a capacitor (C1) for a set time period. This produces the characteristic linear ramp (signal integration period) shown in the figure. At the end of this time period, the voltage across C1 is proportional to the input voltage. A precise positive reference current is then applied to C1, discharging the capacitor at a fixed rate (and producing the other "leg" of the dual slope ramp as shown in the figure). The time required to discharge the capacitor is directly dependent on the voltage appearing across the capacitor at the end of the signal integration period. The reference integration period, representing the value of the input level, is measured and displayed by the digital portion of the instrument.

1.11 SPECIFICATIONS.

1.12 Specifications are shown in table 1.2.

1.13 MISCELLANEOUS.

1.14 Items Furnished.

1.15 The product instruction manual is provided with each instrument.

1.16 Included with instruments equipped with the 51 Option are a 36 pin edge connector, hood, two mounting screws and two lock washers.

1.17 Required Tools and Test Equipment.

1.18 A list of equipment necessary for calibration is given in paragraph 5.5 on page 5.1. For disassembly, a #1 Phillips head screwdriver is required. Instruments equipped with the Model 51 output option require a +5 ± .25 volt (at 200 mA) external source, to utilize the output data.

Table 1.2 - Specifications

DC VOLTAGE	
Full Scale Ranges:	±200 mV, ±2, ±20, ±200, ±2000V (1000V limit)
Resolution:	100 μV on 200 mV range
Polarity:	Automatic bi-polar ± displayed
Accuracy:	1 year, 15°C to 35°C ±(0.1% of reading +0.05% of full scale)
Input Resistance:	2V range 1000 MΩ minimum 200 mV range 100 MΩ minimum 20, 200, and 2000V ranges 10 MΩ
Normal Mode Noise Rejection:	60 dB (1000 to 1), 59 Hz and above at 18 dB/octave to a minimum of 70 dB up to 100 kHz
Common Mode Noise Rejection: (with 1 KΩ imbalance in either lead)	200 mV, 2V ranges 100 dB (100,000 to 1) 20V range 80 dB (10,000 to 1) 200V range 60 dB (1000 to 1) 2000V range 40 dB (100 to 1)
Response Time:	<1.5 second to settle to rated accuracy
Maximum Voltage:	1000V DC or peak AC
Temperature Coefficient: (0°C to 15°C, 35°C to 50°C, 80% RH)	±(.01% of reading +.005% of full scale)/°C

AC VOLTAGE	
Full Scale Ranges:	2, 20, 200, 2000V RMS (500V RMS 40 Hz to 10 kHz, decreasing to 150V RMS at 100 kHz
Resolution:	1 mV RMS on 2V range
Accuracy: **40Hz - 1kHz** **1kHz - 10kHz** **10kHz - 20kHz** **20kHz - 100kHz**	1 year, 15°C to 35°C ±(0.3% of reading +0.05% of full scale) ±(0.4% of reading +0.05% of full scale) ±(0.6% of reading +0.05% of full scale) ±(0.9% of reading +0.05% of full scale)
Input Impedance:	2V range 2 MΩ in parallel with 100 pF All other ranges 1 MΩ in parallel with 100 pF
AC Common Mode Rejection Ratio:	60 dB (1000 to 1) at 60 Hz with 1 KΩ imbalance in Common lead
Response Time:	<2 seconds to settle to full accuracy
Maximum Voltage:	500V RMS to 10 kHz, decreasing to 150V at 100 kHz
Noise:	±1 digit
Temperature Coefficient: (0°C to 15°C, 35°C to 50°C, 80% RH) **40Hz - 1kHz** **1kHz - 10kHz** **10kHz - 100kHz**	 ±(0.02% of reading +0.005% of full scale)/°C ±(0.05% of reading +0.005% of full scale)/°C ±(0.06% of reading +0.005% of full scale)/°C

Table 1.2 - Specifications (continued)

RESISTANCE	
Full Scale Ranges:	200Ω; 2, 20, 200, 2000 KΩ; 20 MΩ
Resolution:	100 milliohms on 200Ω range
Accuracy: 2,20,200 KΩ range 200Ω, 2000KΩ range 20 MΩ range	1 year, 15°C to 35°C ±(0.2% of reading +0.05% of full scale) ±(0.4% of reading +0.05% of full scale) ±(1.0% of reading +0.05% of full scale)
Response Time:	<1 second on 200Ω, 2, 20, 200 KΩ <2 second on 2000 KΩ, 20 MΩ
Current Through Unknown:	Range 200Ω 10 milliamperes 2 KΩ 1 milliampere 20 KΩ 100 microamperes 200 KΩ 10 microamperes 2000 KΩ 1 microampere 20 MΩ 0.1 microampere
Fault Voltage:	250V DC or RMS, fuse protected at 2 amps on all ranges
Maximum Voltage Across Unknown:	2 volts at full scale
Maximum Open Circuit Voltage:	20 MΩ range +5 volts All other ranges +15 volts
Temperature Coefficient: (0°C to 15°C, 35°C to 50°C, 80% RH)	20 MΩ range ±(0.03% of reading +0.005% of full scale)/°C All other ranges ±(0.01% of reading +0.005% of full scale)/°C

DC CURRENT	
Full Scale Ranges:	±20 and ±200 μA; ±2, ±20, ±200, and ±2000 mA
Resolution:	10 nA on 20 μA range
Accuracy: 2000 mA range All other ranges	1 year, 15°C to 35°C ±(0.4% of reading +0.05% of full scale) ±(0.2% of reading +0.05% of full scale)
Shunt Values:	20, 200 μA range 10 KΩ ±0.1% 2, 20 mA range 100 KΩ ±0.1% 200, 2000 mA 1Ω ±0.1%
Voltage Drop: (maximum)	2000 mA, 20 mA, 200 μA rng 2V 200 mA, 2 mA, 20 μA range 0.2V
Fault Current: (all ranges)	Fuse protected to 2 Amps
Temperature Coefficient: (0°C to 15°C, 30°C to 50°C, 80% RH)	±(0.015% of reading +0.005% of full scale)/°C

BCD OUTPUT, Option 51	
Output Code:	BCD 1-2-4-8, Positive True
Output Levels:	True, +2.4V minimum; False, +0.8V maximum
Maximum Readings:	60 per second, external command
Remote Input:	Hold, Read Command
Power Requirements:	Regulated 5V at 200 milliamps

Table 1.2 - Specifications (continued)

ACCESSORIES	
AC Current, Model 86	
Full Scale Ranges:	200 μA, 2, 20, 200, and 2000 mA
Resolution:	100 nA
Accuracy: (50 Hz - 10 kHz)	1 year, 15°C to 35°C
200 μA range	±(0.8% of reading +0.05% of full scale)
2000 mA range	±(0.7% of reading +0.05% of full scale)
All other ranges	±(0.5% of reading +0.05% of full scale)
Shunt Values:	200 μA range 10 KΩ (yellow) 2 mA range 1 KΩ (orange) 20 mA range 100Ω (brown) 200 mA range 10Ω (red) 1000 mA range 1Ω (black)
Response Time:	2 seconds to rated accuracy
Fault Current:	200% of range, 2 thru 200 mA 200% of range, 1000 mA (2 minutes maximum)

High Voltage DC Probe, Model 82	
Maximum Input:	5000V DC
Input Impedance:	900 MΩ
Accuracy:	±2.0% full scale

High Voltage DC Probe, Model 83	
Maximum Input:	50,000V DC
Input Impedance:	900 MΩ
Accuracy:	±5.0% full scale to 45 KV

R.F. Probe, Model 84	
Accuracy:	(accurate measurements to 25V RMS)
1kHz - 10 MHz	±(1.0% of reading +0.5% of full scale)
to 100 MHz	±1 dB at full scale
to 200 MHz	±3 dB at full scale
Input Impedance:	1.5 MΩ
Fault Voltage:	±250V DC or RMS AC

GENERAL	
Digitizing Time:	8 milliseconds
Maximum Common Mode Voltage:	500V DC or RMS AC
Maximum Power Requirement:	10 watts, 115 or 230V
Operating Temperature:	0° to 50°C
Humidity:	80% relative humidity at 35°C to full accuracy
Warmup:	30 minutes to full accuracy
Dimensions:	8.89 cm (3.5 in) x 21.59 cm (8.5 in) x 28.58 cm (11.25 in)
Weight:	2.72 Kgm (6 lbs.) net, 3.62 Kgm (8 lbs.) shipping

SECTION 2 INSTALLATION & OPERATION

2.1 UNPACKING AND INSPECTION.

2.2 The Model 3800B is enclosed between two molded, plastic-foam forms and packaged in a double-walled cardboard carton for shipment. The plastic forms hold the instrument securely in the carton and absorb any reasonable external shock normally encountered in transit. Prior to unpacking, examine the exterior of the shipping carton for any signs of damage. Carefully remove the instrument from the carton and inspect the exterior of the instrument for any signs of damage. If damage is found, notify the carrier immediately.

2.3 POWER REQUIREMENTS.

2.4 Power is supplied to the instrument through a standard, 6 foot, permanently attached, 3-wire, power cable. The power transformer of the DMM is equipped with a dual primary, enabling the instrument to be operated at 115 volts AC or 230 volts AC by the placement of internal jumpers. Jumper locations are indicated in figure 2.1. A .25 amp fuse is used for 115 volt operation and a .125 amp fuse is used for 230 volts, both are 3AG 'normal blow' type fuses.

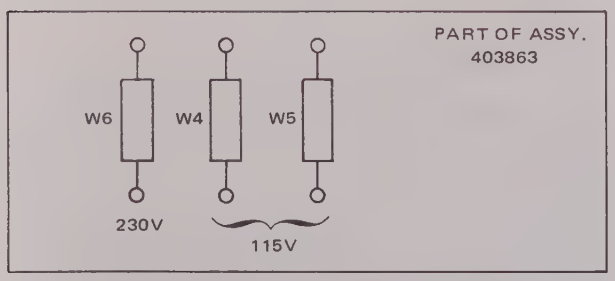


Figure 2.1 - 115/230V Primary Connections

2.5 BENCH OPERATION.

2.6 The DMM, as shipped, is ready for bench operation. A versatile bail handle doubles as a carrying handle and as a 'kickstand' for elevating the front of the instrument, providing easier access to the controls and display.

Table 2.1 - Model 60 Parts List

(1)	Mounting Bracket	403356
(1)	Mounting Bracket	403357
(4)	PPH Screws 6-32 x 7/16	615060
(4)	Lockwasher #6	617079

2.7 MODEL 60 RACK MOUNTING ACCESSORY.

2.8 The rack mounting accessory permits the instrument to be mounted in a standard 19 inch instrument rack or cabinet. It consists of a long and short flange (permitting left or right hand, half-rack mounting) and all necessary mounting hardware as shown in table 2.1. To mount the flanges, proceed as follows:

a. Remove the top cover of the DMM as described in Section 5.

b. Lift out bail handle assembly.

c. Remove the two bottom screws from the two side panel inserts and remove the metal decorative inserts.

d. Replace the top cover and reinstall the two screws at the rear panel.

e. Mount the flanges in the spaces vacated by the side panel inserts, with the hardware provided in the kit.

2.9 CONTROLS AND INDICATORS.

2.10 The readout and all controls are located on the front panel (shown in figure 2.2) and described below.

2.11 Power Switch.

2.12 The POWER switch is a two position push-on, push-off switch. The ON position applies power to the instrument which immediately begins taking readings at a rate of 6 per second. The OFF position removes power to all portions of the instrument.

2.13 Offset.

2.14 The OFFSET is a flat blade screwdriver adjusted control used to zero the instrument readout. This control can also be used to adjust out unwanted levels from the signal source.

2.15 Range Control.

2.16 The range control is a six position rotary switch that selects the available ranges for each function as shown in table 2.2.

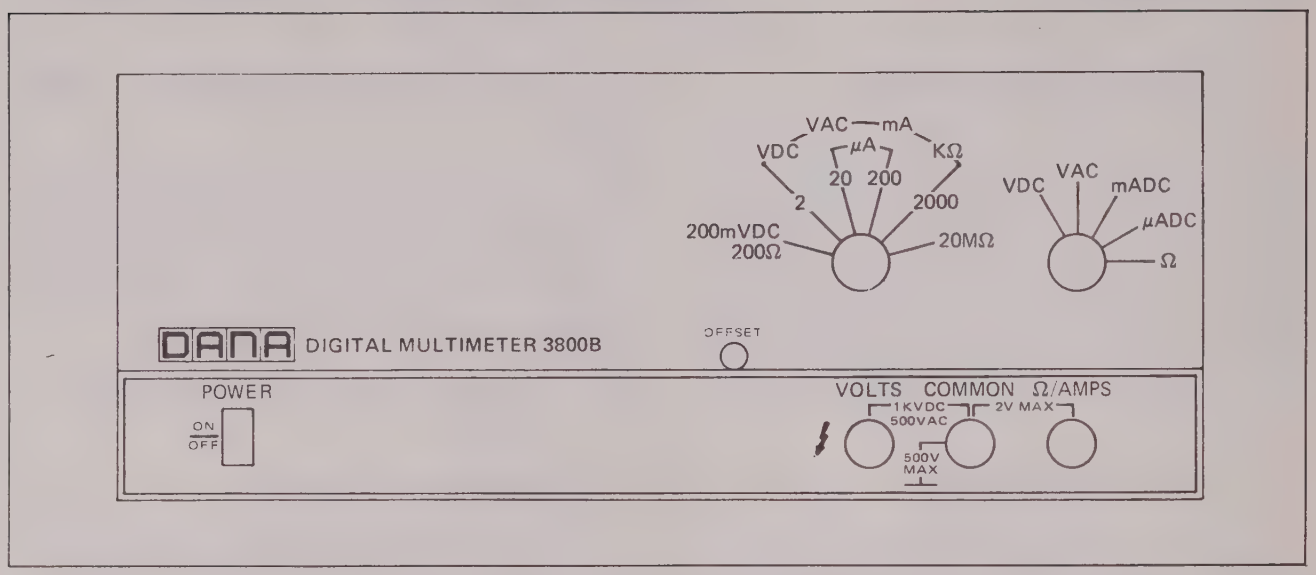


Figure 2.2 - Model 3800B Front Panel

2.17 Function Control.

2.18 The function control is a five position rotary switch that selects the type of measurement required. The positions are:

VDC — Measures DC voltages, with full scale ranges from 200 millivolts to 2000 volts (1000 volts maximum).

VAC — Measures AC voltages, with full scale ranges from 2 volts to 2000 volts (500 volts maximum).

mADC — Measures DC milliamps, with full scale ranges from 2 milliamps to 2000 milliamps.

μADC — Measures DC microamps, with full scale ranges of 20 μA and 200 μA.

Ω — Measures resistance, with full scale ranges from 200 ohms to 20 megohms.

2.19 Display.

2.20 The display consists of three 7-segment numeric LEDs and an overrange and polarity LED. An overload condition is indicated by a blinking display.

2.21 Signal Input Terminals.

2.22 The signal input consists of three terminals set in-line and spaced to permit the use of a dual "banana plug" between the center and either of the two outside terminals. The center terminal (black) is the COMMON terminal and all voltage and current measurements are referenced to it. The left terminal (red) is the VOLTS terminal and AC and DC voltage measurements are made with this and the COMMON terminal. The VOLTS terminal is tied into the measurement circuitry only when VDC or VAC function is selected; in all other functions, this terminal is open. The right terminal (white) is the Ω/AMPS terminal. It is used in conjunction with the COMMON terminal to measure resistance and current. The Ω/AMPS terminal is

Table 2.2 - Range Control, Available Range

Function	Ranges					
VDC	200 mV	2V	20V	200V	2000V	–
VAC	–	2V	20V	200V	2000V	–
mADC		2 mA	20 mA	200 mA	2000 mA	–
μADC	–	–	20 μA	200 μA	–	–
Ω	200Ω	2 KΩ	20 KΩ	200 KΩ	2000 KΩ	20 MΩ

Table 2.3 - Maximum Allowable Inputs

VDC	1000V DC or peak AC
VAC	500V RMS 40 Hz to 10 kHz, decreasing to 150V RMS at 100 kHz
ADC	Fuse protected at 2 amps
Ω	Fuse protected at 2 amps

tied into the circuitry only when mADC, μADC, or Ω is selected; in all other functions, this terminal is open.

2.23 OPERATING PROCEDURE.

2.24 The instrument is designed for the simplest possible level of operation. Once the instrument has been connected to the power line and to the signal source in accordance with the instructions, the operator can make all the required measurements by setting the front panel controls to the desired positions.

2.25 Test Leads.

2.26 Three general usage test leads (Options 80, 88, and 89) are available for use with the instrument, or the user may choose to fabricate his own.

2.27 Maximum Inputs.

2.28 The maximum allowable inputs for each function and range combination is illustrated in table 2.3.

2.29 ACCESSORIES.

2.30 A full line of accessories are available for the instrument. These are described below:

60, Rack Mounting Flanges. These flanges permit the instrument to be mounted in a standard 19 inch rack or cabinet and are described in full, beginning with paragraph 2.7.

80, Shielded Input Cable. This is a 5 foot long shielded cable with hooded alligator clip probes and dual banana plug for mating the cable to the instrument. This input cable is especially useful in high noise environments.

82, 5 KV High Voltage Probe. This probe extends the DC measurement capability of the instrument to 5000 volts. The probe is used on the 20 and 200V DC ranges only.

83, 50 KV High Voltage Probe. This probe extends the DC measurement capability of the instrument to 50,000 volts. The probe is used on the 20 and 200V DC ranges only.

84, RF Probe, 200 MHz. This probe extends the capabilities of the instrument to the measurement of RF frequency. The probe measures frequencies from 1 kHz to 200 MHz at RMS voltage levels up to 25 volts. Input impedance is 1.6 megohms. The probe converts the RF signal to the DC equivalent voltage and is measured on the instruments 20V DC range.

86, AC Current Shunts. This accessory extends the instrument's measurement capabilities to include AC current measurement. AC currents to 10 kHz are accurately measured with full scale inputs of 200 μA, 2 mA, 20 mA, 200 mA, and 2000 mA. The accessory consists of five precision, shunt resistors, molded in color-coded dual banana plug/sockets. The desired shunt is connected between the instrument and the input cable. All AC current measurements are made on the 2 volt AC range.

88, Deluxe Test Lead Set. These test leads are designed to withstand the everyday continuous on the line use of production testing or field use. The probes come equipped with separate assorted tips.

89, Standard Test Leads. These are standard test leads with 90 degree banana plugs and replaceable 'phonograph needle' tips.

SECTION 3 BCD OUTPUT

3.1 GENERAL.

3.2 The Isolated BCD Output (Option 51) converts the readout, range and polarity data into binary form for printers or other digitally operated equipment. The output of the option is completely isolated, preserving the instruments common mode rejection characteristics, even when connected to grounded equipment.

3.3 MECHANICAL DESCRIPTION.

3.4 All components for the option are on a single printed circuit board that is mounted above the instrument's main PCB by four spacers; an aluminum shield is placed between the boards to prevent digital noise generated by the option from affecting measurement circuitry on the main board. One end of the option board forms an edge connector that extends out of the back of the instrument through a slot provided for this purpose. This connector is the BCD option output connector and is designated J4.

3.5 Data and the power required for the isolated portion of the board is routed through a 14-wire cable that plugs into connector J2 on the main board and J3 on the option board. The option requires an external +5 volt power supply (5 volts ± .25 volts at 200 mA) to be provided by the user, to supply power to the grounded portion of the option.

3.6 ELECTRICAL DESCRIPTION.

3.7 As shown in figure 3.1, isolation between the measurement portion of the instrument and the grounded output portion of the option is maintained by the use of two pulse transformers and four optical couplers. All data is passed through these six devices. The output data is from TTL logic and in positive true 1-2-4-8 BCD or single line form.

3.8 The Display data is generated by coupling the clock oscillator output through pulse transformer T1 to a three decade counter consisting of U5, U6, and U7; the output of the counter (100_8) drives flip flops U8 and U9 that generate overrange and overload (decade U10 is not used). The counter and flip flops are reset by the $\overline{\text{RESET}}$ pulse of the instrument after passing through isolation transformer T2. The option counter advances at the same rate as the decade counter of the DMM and, at the completion of a measurement cycle, the value of the display is stored in binary form by the option counter.

3.9 The range data is encoded on the isolated portion of the option by a four diode matrix and passed through two optically coupled isolators (OCI-3 and OCI-4).

3.10 The polarity is coupled through OCI-1 and controls 'D' flip flop U8. The flip flop is strobed by the isolated $\overline{\text{RESET}}$.

3.11 The PRINT pulse is a 10 millisecond pulse generated by one shot U2, U4. The PRINT line goes false upon receipt of a negative going $\overline{\text{RESET}}$ pulse (coinciding with the start of a measurement cycle). Ten milliseconds later the one shot goes true, signifying the output data is ready to be recorded. A $\overline{\text{PRINT}}$ output is provided for equipment requiring a negative going print command signal.

3.12 The $\overline{\text{HOLD}}$ line, in conjunction with the read command circuitry, generates an isolated $\overline{\text{HOLD}}$ signal at the output of OCI-2. This signal inhibits the generation of new readings by locking up the ÷10 counter U10 on the main logic board (see Section 4). The instrument holds the last reading until the hold line is released or when commanded to, by a $\overline{\text{READ COMMAND}}$ signal.

3.13 The READ COMMAND circuitry consists of a 'D' flip flop (U9) wired to generate a logic false at $\overline{Q}$ when the $\overline{\text{READ COMMAND}}$ line is pulled to logic false. This causes the $\overline{\text{HOLD}}$ output of OCI-2 to go true and allows a new measurement cycle to start. U9-$\overline{Q}$ goes true 10 ms after the start of the read cycle when $\overline{\text{PRINT}}$ goes false, that applies a capacitor coupled negative going pulse to U9-CLEAR.

3.14 OPERATION.

3.15 Provided with the option 51 is the Connector assembly that includes a mating connector and hood, and mounting screws w/lock washers for securing the connector and hood to the back of the instrument. No special shielding considerations are required for cabling. Pin locations are indicated in table 3.1.

3.16 External Supply.

3.17 An external supply capable of providing a voltage level between +4.75 to +5.25 with a current of 200 milliamps is required to power the components of the grounded portion of the option. The +5 volts is introduced to J4 pin V and referenced to J4 pin 18.

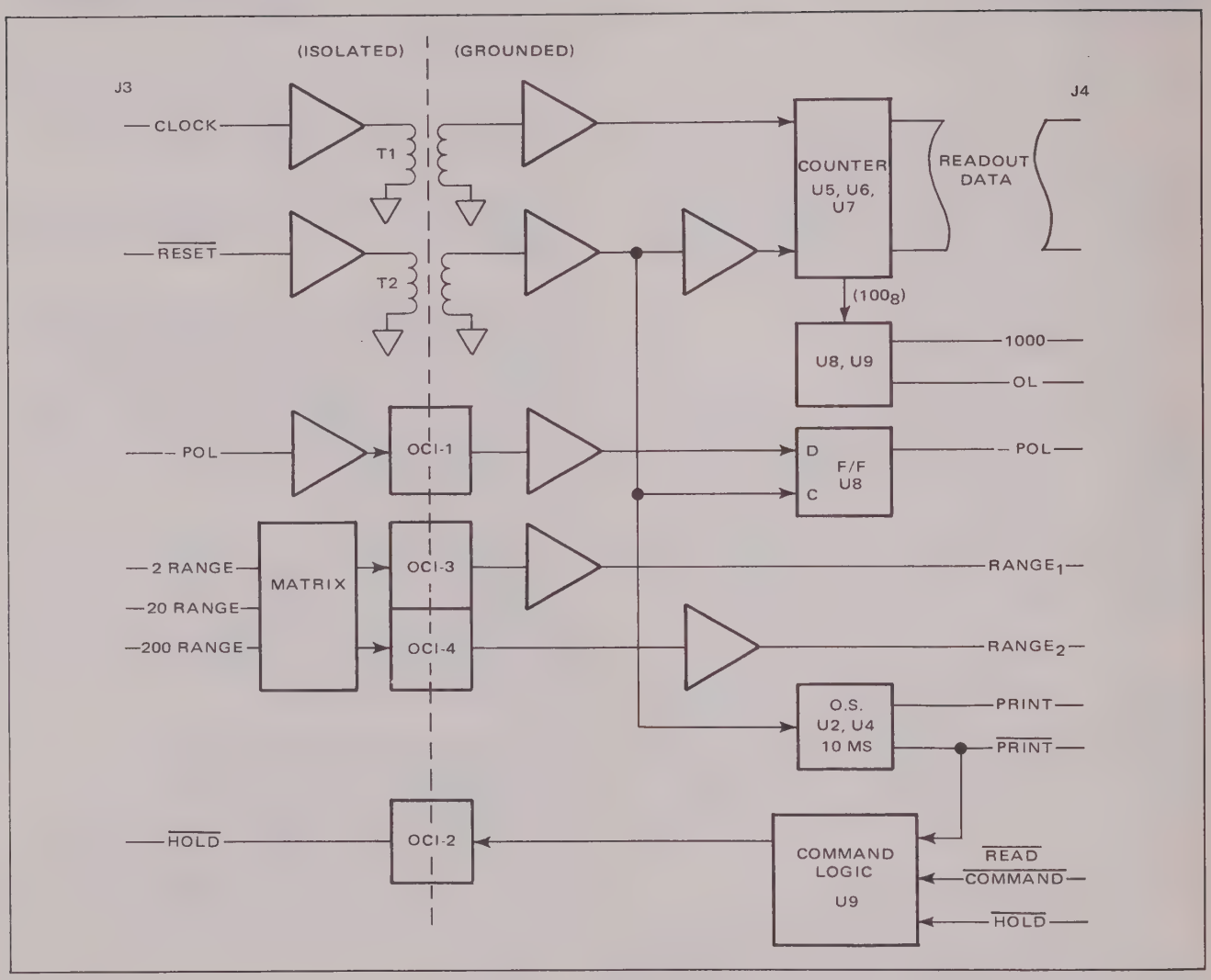


Figure 3.1 - BCD Output

3.18 Output Lines.

3.19 All output lines are driven by TTL logic and referenced to common (J4-18). Output levels are defined below:

LOGIC TRUE = +2.4 minimum

LOGIC FALSE = +0.8 maximum (16 mA current sink)

3.20 COMMANDS.

3.21 Commands are initiated by bounce free contact closure or NPN switch closure to common (J4-18).

3.22 $\overline{\text{HOLD}}$.

3.23 When the Hold line is allowed to float true, the instrument takes readings and print pulses are generated at a rate of 6 per second. When the Hold line is selected, the last instrument reading is retained and no new measurements are taken.

3.24 $\overline{\text{READ COMMAND}}$.

3.25 A Read Command is used only when Hold is selected and permits the user to command a reading at any time up to 60 measurements a second. A suitable Read Command pulse is shown in figure 3.2.

Table 3.1 - BCD Output Pin Locations

	J4		
Not Used	1	A	Not Used
Not Used	2	B	Not Used
$\overline{\text{READ COMMAND}}$	3	C	$\overline{\text{HOLD}}$
Not Used	4	D	– POL
Not Used	5	E	Not Used
Not Used	6	F	Not Used
Not Used	7	H	$\overline{\text{OL}}$
Not Used	8	J	Not Used
Not Used	9	K	Not Used
Not Used	10	L	Not Used
100's 8	11	M	100's 2
100's 4	12	N	100's 1
PRINT	13	P	$\overline{\text{PRINT}}$
10's 8	14	R	10's 2
10's 4	15	S	10's 1
Units 8	16	T	Units 2
Units 1	17	U	Units 4
COMMON	18	V	External +5V

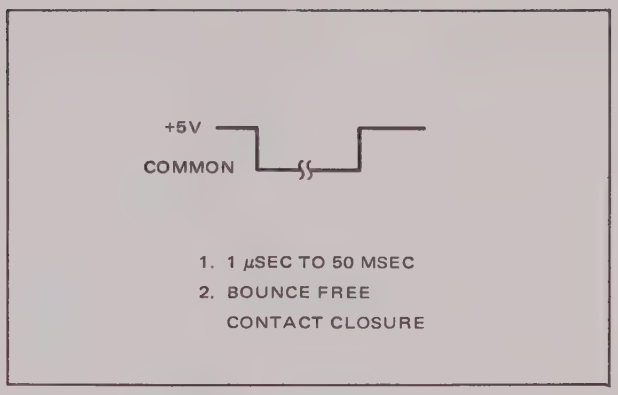


Figure 3.2 - Read Command

SECTION 4 THEORY OF OPERATION

4.1 GENERAL.

4.2 This section describes the operation of the Model 3800B DMM. The section is divided into two parts, corresponding to the analog and digital divisions of the instrument. Drawings appearing in this section are included to supplement the assembly and schematic drawings located in Section 6.

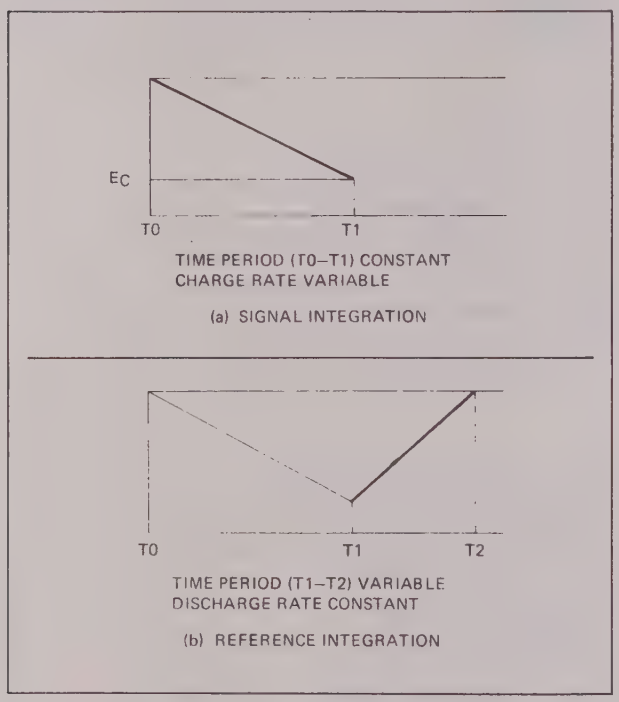


Figure 4.1 - Dual Slope Integration

4.3 The Series 3800B DMM uses the dual slope integration method of analog-to-digital conversion. In this method, a DC input is converted into a proportional, negative current. The value of the current produced is a function only of the absolute value of the input signal, being independent of the polarity of the input signal. The current generated is fed to a capacitor which integrates the current, developing a linearly increasing negative charge as shown in figure 4.1(a). The negative current is applied to the capacitor for a specific time period. The time period (T0 = T1) is controlled by a clock driven counter in the digitizing and display portion of the DMM and is equal to 1000 clock cycles. At the completion of this signal integration period (T1), the voltage developed across the capacitor is converted into a proportional time period by replacing the input current with a known, positive, reference current. The positive current causes the voltage across the capacitor to linearly decrease as shown in figure 4.1(b). This reference integration period (T1 - T2) terminates when the voltage across the capacitor is restored to its original, premeasurement level (T0). The start of the reference integration period (T1) coincides with the counter being set to 0000 and the completion of the period (T2) halts the counter. The reference integration period (T1 - T2), which is proportional to the value of the input signal, controls the number of clock cycles registered by the counter. The value of reference current is opposite in polarity but equal in value to the signal current produced by a one volt input. For a one volt input the reference integration period (T1 - T2) and the counter registers 1000. For a 0.5 volt input the reference integration period is one half as long and the counter registers 500. At the completion of the reference integration period the position of the counter is displayed and numerically represents the value of the input voltage.

4.4 SIGNAL CONDITIONING.

4.5 The signal conditioning portion of the instrument is shown simplified in figure 4.2. Prior to measuring by the Analog-to-Digital section of the DMM, the input signal is converted to a maximum DC level of ±2 volts. The isolator portion of the A to D converter operates at a gain of one or ten depending on the range and function selected (see table 4.1). The scaled input is limited to ±0.2 volts when the isolator operates at a gain of 10. The input signal is routed through the function control switch (S1) to the appropriate conditioning circuitry. The conditioned signal is routed again through S1 to the A to D converter.

Table 4.1 - Isolator Gain

Range	DC	AC	MA	μA	Ohms
.2	X10				X1
2	X1	X1	X10		X1
20	X1	X1	X1	X10	X1
200	X1	X1	X10	X1	X1
2000	X1	X1	X1		X1
20,000					X1

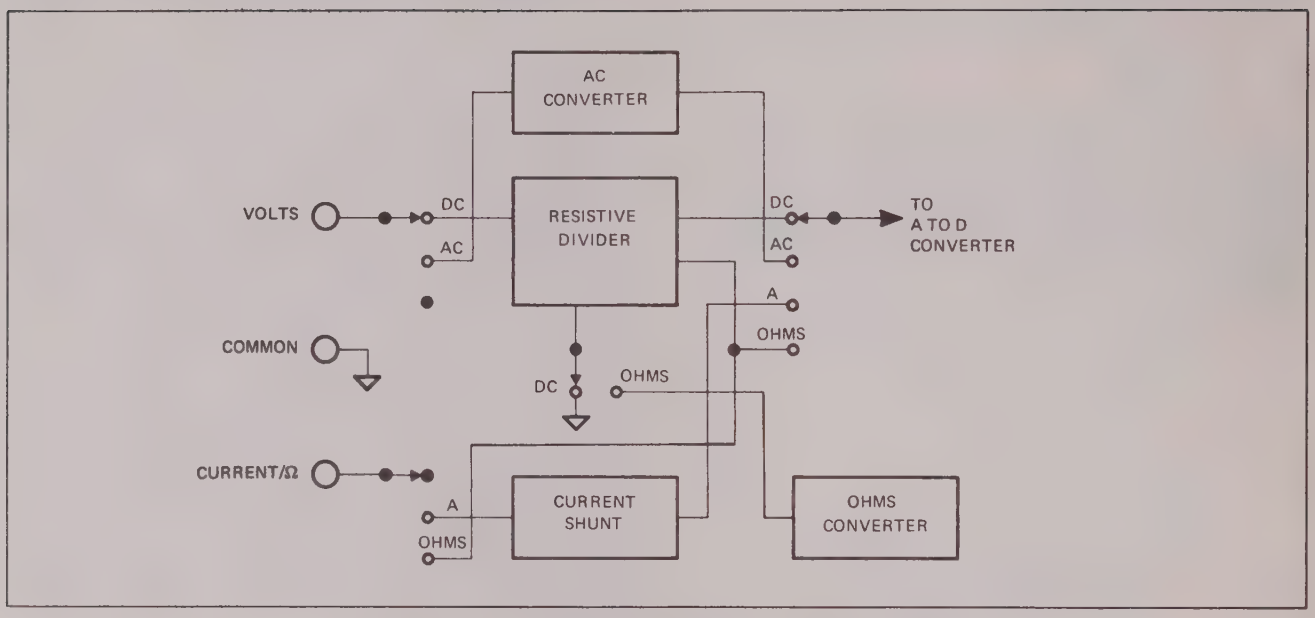


Figure 4.2 - Block Diagram – Signal Conditioning Section

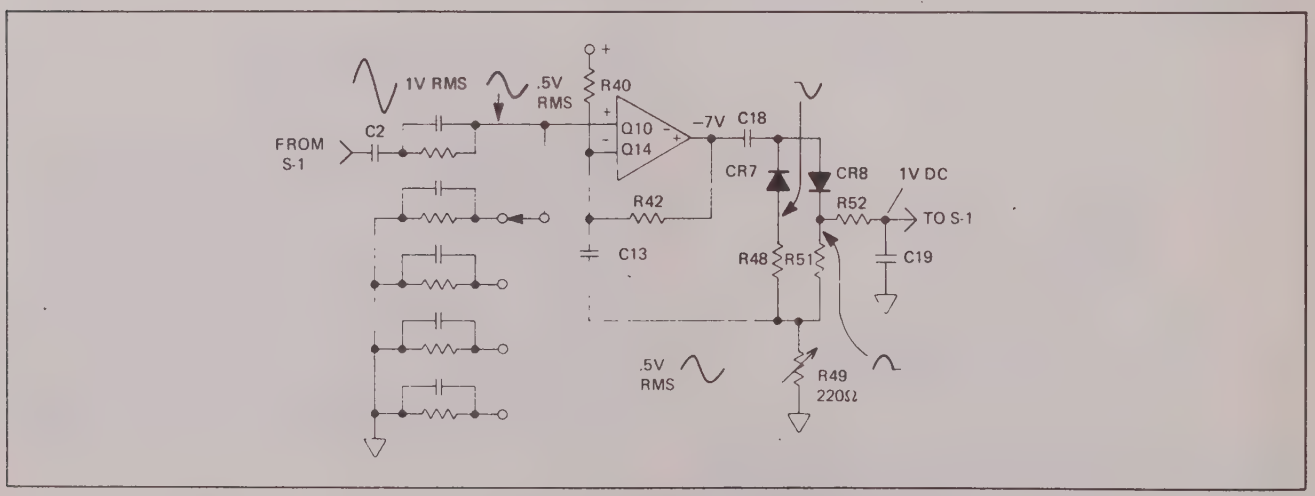


Figure 4.3 - Simplified AC Converter

4.6 DC.

4.7 The DC input is applied to the range divider where it is scaled and routed to the A to D converter. On the .2 and 2 volt ranges, no attenuation of the signal takes place. On the 20, 200, and 2000 ranges the input signal is scaled by a factor of .1, .01, and .001, respectively. The additional resolution required for the 2 range is supplied by the isolator.

4.8 AC.

4.9 The AC converter, shown simplified in figure 4.3, converts an AC input to an equivalent DC signal. The AC signal is scaled by the AC converter attenuator by a factor of .5 on the two volt range and by .05, .005, and .0005 on the 20, 200, and 2000 volt ranges, respectively. The scaled input is amplified by the potentiometric amplifier consisting of transistors Q10 through Q14. The amplified AC

signal is fed through C18 to two polarity dependent feedback paths, CR7 and R48, and CR8 and R51, which divide the task of conducting the signal. CR7 and R48 conduct during the negative half of the AC signal and CR8 and R51 during the positive half. The bisected signal is summed across R49 and fed back through capacitor C13 to the reference input of the amplifier. The closed loop gain of the amplifier determined by R48, R51, and R50 is approximately 4.5. The positive half cycle developed across R51 is filtered by R52 and C19 to produce a positive DC equivalent of the AC input. Further filtering is performed on the DC output by the active filter of the Analog-to-Digital converter section.

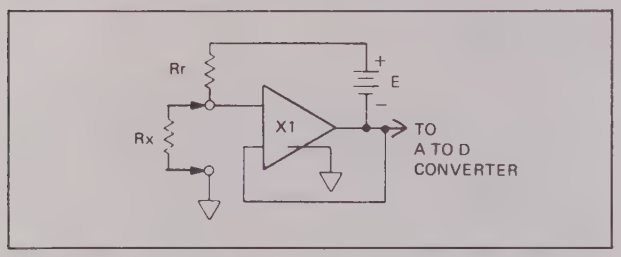


Figure 4.4 - Basic Ohms Converter

4.10 Ohms.

4.11 The ohms converter produces a precise DC current which is fed through the resistance being measured. The resultant DC voltage drop across the resistor is measured and displayed. The current generated for each range is chosen to produce a two-volt drop across a resistance equal to the range selected. Thus, on the 2K range, a current of 1 milliamp is produced developing a two-volt drop across an input resistance of 2 Kohm. The current produced on each range is given in table 4.2.

Table 4.2 - Ohms Converter Current Output

Range	Current
200 Ohms	10 mA
2 Kohms	1 mA
20 Kohms	100 μA
200 Kohms	10 μA
2 Megohms	1 μA
20 Megohms	100 nA

4.12 A simplified diagram of the ohms converter is shown in figure 4.4. The voltage developed across the resistance being measured (Rx) is buffered by a gain of one amplifier. The ohms converter generates a precise voltage (E), referenced to the amplifier output. The voltage is connected to a precise range resistor (Rr) and (Rx), connected in series. Because the voltage (E) follows the voltage developed

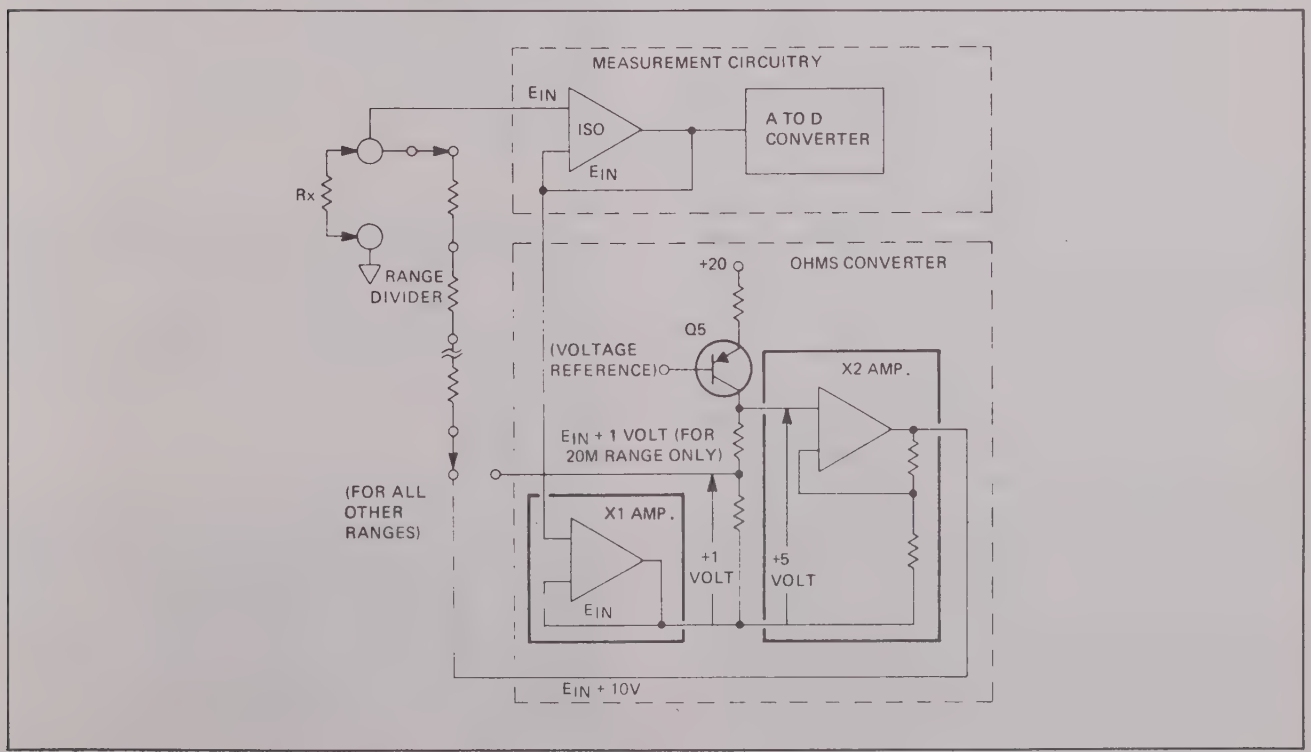


Figure 4.5 - Simplified Ohms Converter

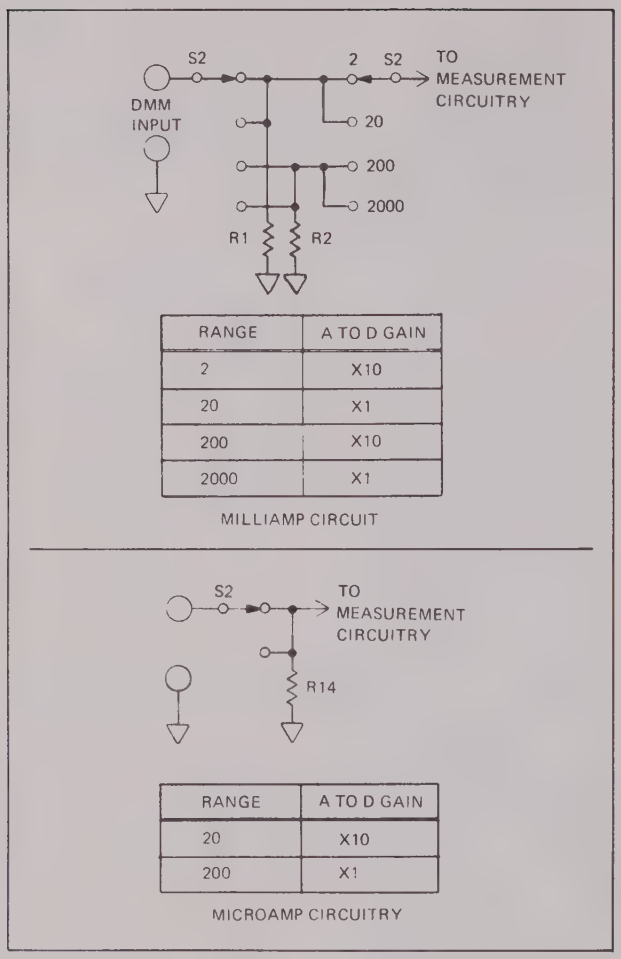


Figure 4.6 - Simplified DC Current Circuits

across (Rx), the voltage impressed across (Rr) is constant, making the current through (Rx) constant. The input resistance of the gain of one amplifier is extremely high. Effectively, therefore, all of the current flowing through (Rr) also flows through (Rx).

4.13 For measuring ohms, the converter is used in conjunction with other portions of the DMM circuitry as shown in figure 4.5. The isolator from the A to D converter provides the required isolation and precise gain-of-one accuracy for monitoring the voltage drop across resistor Rx. The output of the isolator is buffered by a gain-of-one amplifier (consisting of transistors Q1 through Q4) on the ohms converter. To the output of the buffer amplifier is connected a network producing two precise voltage outputs. The network consists of a current generator Q5, which is referenced to the DMM's + REFERENCE VOLTAGE, driving a stable 0.5 milliamps through resistors R20 and R22 connected in series. The voltage drop across R22 is +1 volt and is used only on the 20 Meg range. The voltage drop across the two resistors is +5 volts. This level is increased to +10 volts by a gain-of-two amplifier consisting of transistors Q6 through Q9; the 10 volt level is used on all ranges except the 20 Meg range. Both the +1 volt and +10 volt levels float above the DMM input level.

4.14 The converter voltage output is routed through a precision, series-divider, consisting of the same resistive string used for the DC range divider. The Range Control selects the amount of resistance (Rr) placed in series with the converter voltage output and Rx, thereby controlling the current produced for each range.

4.15 DC Current.

4.16 Two current positions, milliamp and microamp, are provided on the Model 3800B DMM. Both functions use internally selected shunts to convert the input current to an equivalent voltage for measurement. As shown in figure 4.6, two shunt resistors are used for the milliamp function and one shunt for the microamp function. The gain of the A to D converter is increased to provide the required resolution on the 20 microamp, 2 milliamp and 200 milliamp ranges.

4.17 ANALOG-TO-DIGITAL CONVERTER.

4.18 The Analog-to-Digital (A to D) converter shown in figure 4.7, converts the input signal to a proportional time period for measurements by the digital section.

4.19 Filter.

4.20 The active bessel-type filter shown simplified in figure 4.8 provides 60 dB of normal mode rejection at or near 60 Hz and consists of transistor Q15 and Q16. The transistors provide a moderately high degree of amplification and through the feedback path (R54, R57, C20, and C22) operate with the source impedance to produce an active 3-pole filter.

4.21 Isolator.

4.22 The isolator is a high gain, high input impedance, DC amplifier, consisting of a differential, dual FET (Field Effect Transistor) input stage, driving an integrated circuit amplifier. The isolator (shown in figure 4.9) is operated potentiometrically to provide a closed-loop gain-of-one. The signal input of the isolator is clamped by transistors Q50 and Q51, connected as diodes, to limit the signal swing to approximately plus or minus 2.2 volts.

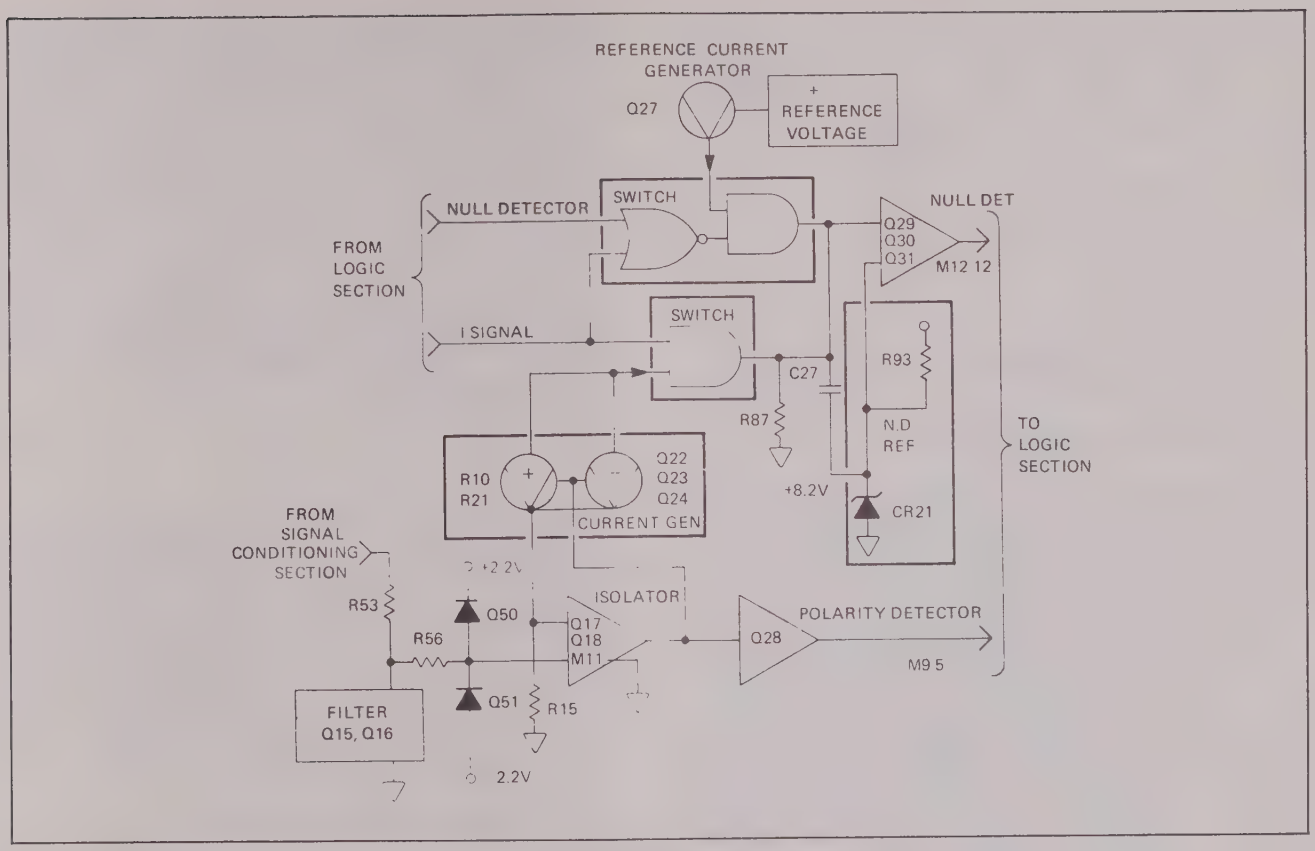


Figure 4.7 - Analog-to-Digital Converter

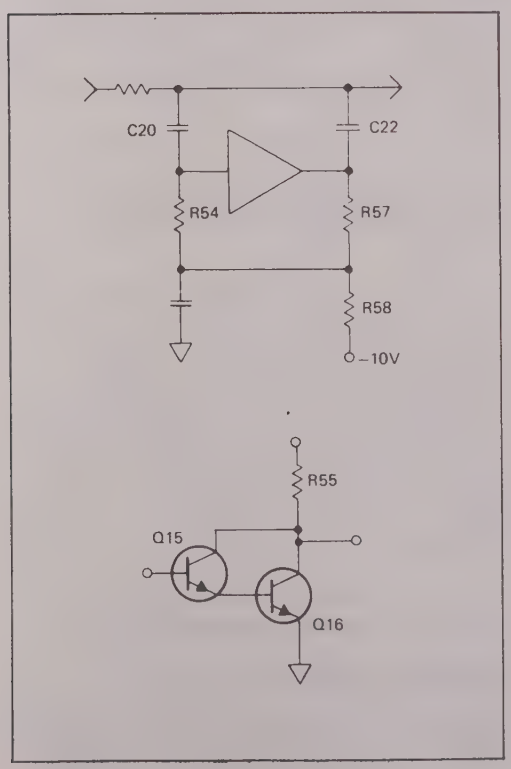


Figure 4.8 - Simplified Filter Schematic

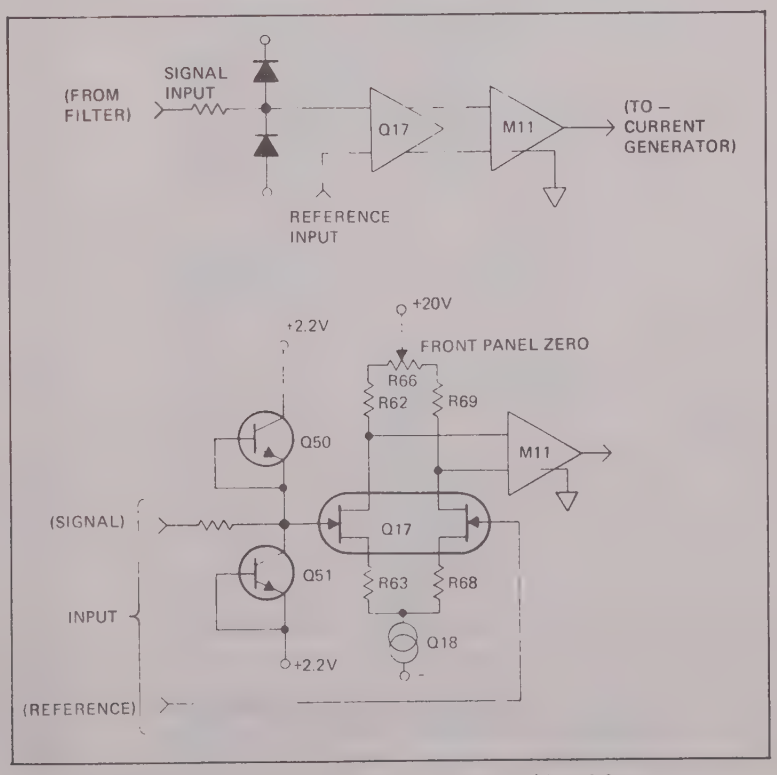


Figure 4.9 - Block Diagram – Isolator/Amplifier

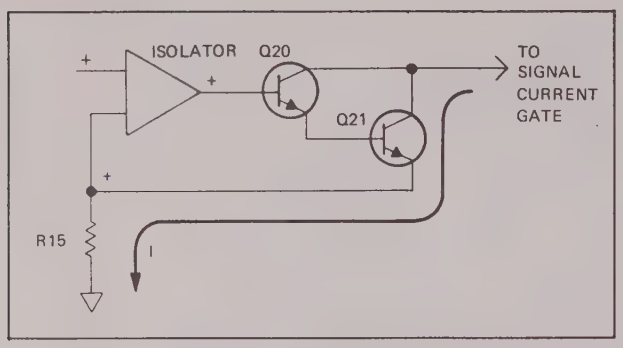


Figure 4.10 - Positive Input Signal Current Generator

4.23 Signal Current Generators.

4.24 The signal current generators operate with the isolator to produce a negative current proportional to the isolator input voltage. One converter operates only during positive inputs and the other only during negative inputs. Shown in figure 4.10 is a simplified schematic of the positive signal current generator. Transistors Q20 and Q21 are connected in a Darlington configuration and may be considered as a single, extremely high beta transistor. A positive level at the input of the isolator produces a high amplified, positive output to the base of Q20-Q21 causing it to conduct. Current flows through the current gain resistor causing a positive I-R voltage drop to develop across the resistor. The network stabilizes when the I-R drop is equal to the positive isolator input level. The current flowing through the resistor is equal (for all practical purposes) to the current drawn by the Q20-Q21 collector. The current through the current gain resistor varies directly with the isolator input, making the current drain (negative current) from Q20-Q21 directly proportional to the isolator input.

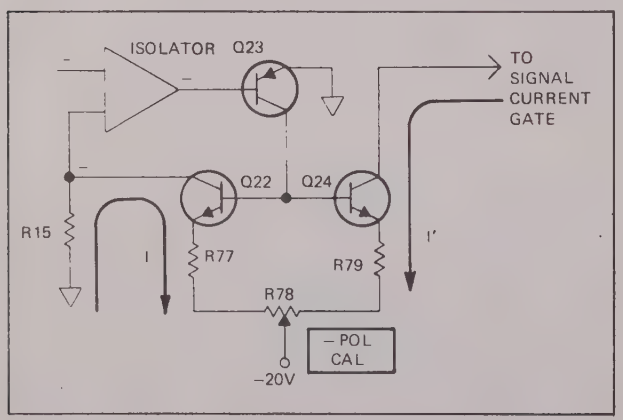


Figure 4.11 - Negative Input Signal Current Generator

4.25 The negative signal current generator shown in figure 4.11 consists of transistors Q22, Q23, and Q24. Transistors Q22 and Q24 have matched characteristics and the emitter circuits are balanced, causing the transistors to draw equal amount of current when conducting. When the input of the isolator is negative, the amplified negative output drives transistor Q23 on, driving current into the bases of Q22 and Q24. The current through Q22 flows also through the gain resistor developing a negative I-R drop across the resistor. The circuitry stabilizes when the negative voltage drop across the gain resistor equals the negative isolator input level. The current drain (negative current) developed by Q24 forms the output of the negative signal current generator and is equal to the current drawn by Q22. It is therefore directly proportional to the negative isolator input.

4.26 Gain Circuit.

4.27 The gain circuit determines the amount of negative current generated by the signal current generators. Normally the gain is determined by R15 (2K) which produces a signal current output of 0.5 milliamps for a ±1 volt input to the isolator. On certain function-range combinations R15 is shunted by R19, lowering the combined resistance to 200 ohms. This increases the amount of current produced by the signal current generator by a factor of 10. Function/range combinations are given in table 4.1.

4.28 Voltage Reference Source.

4.29 The voltage reference source provides a precise and stable, positive DC level for the reference current generator and ohms converter. The reference is a selected High Stability Reference diode, biased for a zero temperature coefficient.

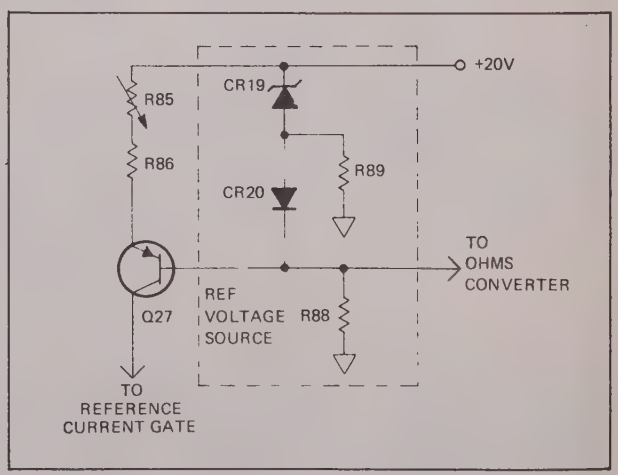


Figure 4.12 - Reference Current Generator

4.30 REFERENCE CURRENT GENERATOR.

4.31 The reference current generator (figure 4.12) produces a stable and highly accurate, positive current of 0.5

milliamps. The converter consists of transistor Q27 biased through CR20 to the voltage reference source, and emitter resistors R85 and R86. Resistor R85 is set to allow 0.5 milliamps of positive current to flow through Q27. Diode CR20 provides temperature compensation for the reference current generator and ohms converter current generator.

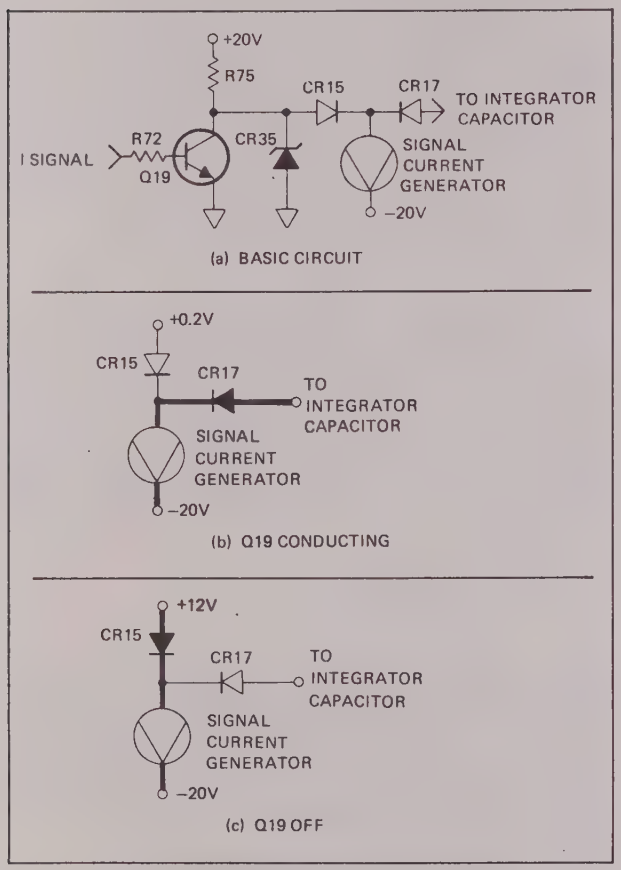


Figure 4.13 - Simplified Signal Gate Circuit

4.32 SIGNAL CURRENT GATE.

4.33 The signal current gate controls the flow of current from the signal current generators, routing the flow to the integrator capacitor or to a positive supply. The signal current gate is operated by I SIGNAL from the logic section of the DMM. The basic circuitry of the gate is shown in figure 4.13(a). During the time that I SIGNAL is true, transistor Q19 is turned on, holding gate diode CR15 to approximately +0.2 volts.

4.34 When I SIGNAL is false, CR15 is held to +12 volts by zener CR35. The current flow through the gate is shown with Q19 conducting in figure 4.13(b). CR15 is back-biased prohibiting current flow; CR17 is forward-biased, allowing all of the current from the signal current generators to flow into the integrator capacitor. With Q19 off, the operation is reversed and all of the current flow is through diode CR15.

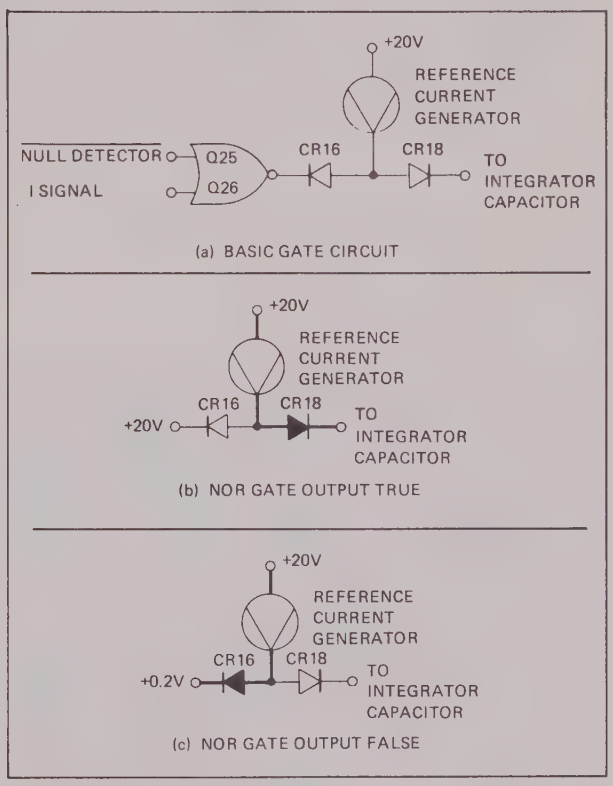


Figure 4.14 - Reference Control Gate Circuit

4.35 REFERENCE CURRENT GATE.

4.36 The reference current gate controls the flow of current from the reference current generator, routing the flow to the integrator capacitor or to analog common. The reference current gate is operated by a NOR gate consisting of transistors Q25 and Q26. When input lines $\overline{\text{NULL DETECTOR}}$ and I SIGNAL are both false the nor gate output is +20 volts; when either input line is true the nor gate output is +0.2 volts. Both nor gate input lines are generated in the logic section. The basic circuitry of the gate is shown in figure 4.14(a). During the time both $\overline{\text{NULL DETECTOR}}$ and I SIGNAL lines are false the cathode of CR16 is held to +20 volts. When either or both of the input lines are true, the cathode of CR16 is held to +0.2 volts. Figure 4.14(b) shows the current flow through the gate with the nor gate output true. CR16 is back-biased, prohibiting current flow; all of the current from the reference current generator flows through forward-biased CR18. In figure 4.14(c), current flow is shown with the nor gate output false. Current flows through forward-biased CR16 and no current flows through back-biased CR18.

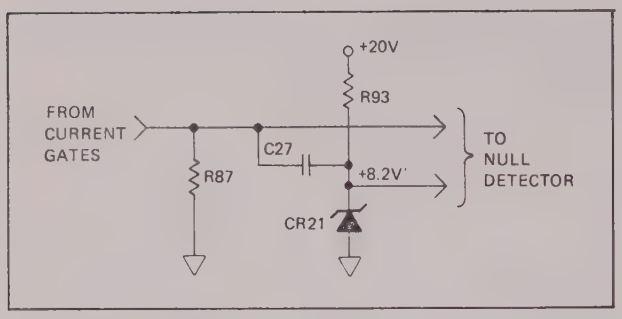


Figure 4.15 - Integrator Circuit

4.37 Integrator Circuit.

4.38 The integrator circuit converts the currents from the signal and reference generators into the dual slope ramp shown in figure 4.1. During the signal integration period, the integration capacitor (C27) is charged negatively by the negative current from the signal current generator flowing through the signal current gate. The capacitor is then discharged by the positive current from the reference current generator through the reference gate. As shown in figure 4.15, the capacitor is referenced to +8.2 volts by zener CR21. The positive level produces required bias for the null detector circuit and simplifies the design requirements for the current gate circuits. Resistor R87 provides a very high resistance shunt (100 Megohms), for C27. During the measurement cycle, the resistor does not affect the operation of the circuitry. When the instrument is placed in external HOLD (on DMM's equipped with Option 51) for long periods of time, the R87 operates in conjunction with the null detector and reference current to hold the capacitor at its operating level.

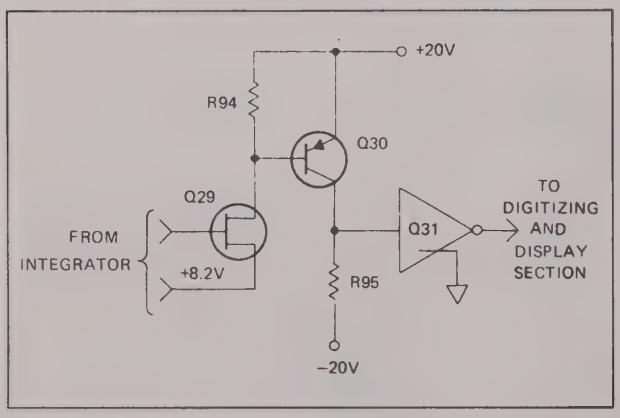


Figure 4.16 - Null Detector

4.39 Null Detector.

4.40 The null detector monitors the voltage across the integrator capacitor, and converts the integration time period into a digital output. The null detector produces a true (positive) output whenever the voltage across the integrator capacitor is below a positive operating level determined by the null detector, and a false output when the capacitor voltage is equal to or above the operating level.

4.41 The null detector circuit is shown simplified in figure 4.16. The input of the null detector is a junction FET (Q29), providing an extremely high input impedance to the integrator circuit. The source of the FET is biased to +8.2 volts by zener CR21 of the integrator circuit, holding the cutoff point of the FET above ground. The FET drives Q30 which inverts and amplifies the FET output. Q30 in turn drives a single stage inverting amplifier Q31.

4.42 The operating level of the null detector (the point at which the null detector changes state) is equal to the +8.2 voltage bias at the FET source, less the inherent cutoff point of the junction FET; the cutoff point of the junction FET varies from one device to another. The operating point therefore may lie anywhere between +2V and +6V. The level of the operating point however, does not require compensation, nor does it alter the operation of the instrument.

4.43 Polarity Detector.

4.44 The polarity detector monitors the output of the isolator and generates a true logic level whenever the isolator output is negative. The polarity detector output drives the polarity indicator circuitry of the digitizing and display portion of the DMM. The detector is a single stage inverting amplifier consisting of Q28.

4.45 DIGITIZING AND DISPLAY.

4.46 The digitizing and display section measures the time required for the reference integration period and converts the measured time into a digital display. The D/D section also determines the time required for the signal integration period and establishes the number of readings taken per second.

4.47 The DMM readout voltage supply is an unfiltered, half-wave +9 volts. The readout therefore is illuminated 60 times a second and only during each half cycle of the line voltage. The measurement cycle is synchronized with the line frequency and each measurement sequence takes place during a readout blank period (less than 8.3 ms). The instrument takes 6 measurements each second. The Digitizing and Display section (shown simplified in figure 4.17) consists of a binary counter, driven by a clock-oscillator. The counter advances at the clock rate (approximately 340 kHz) from 0000 to 3999 and then overflows

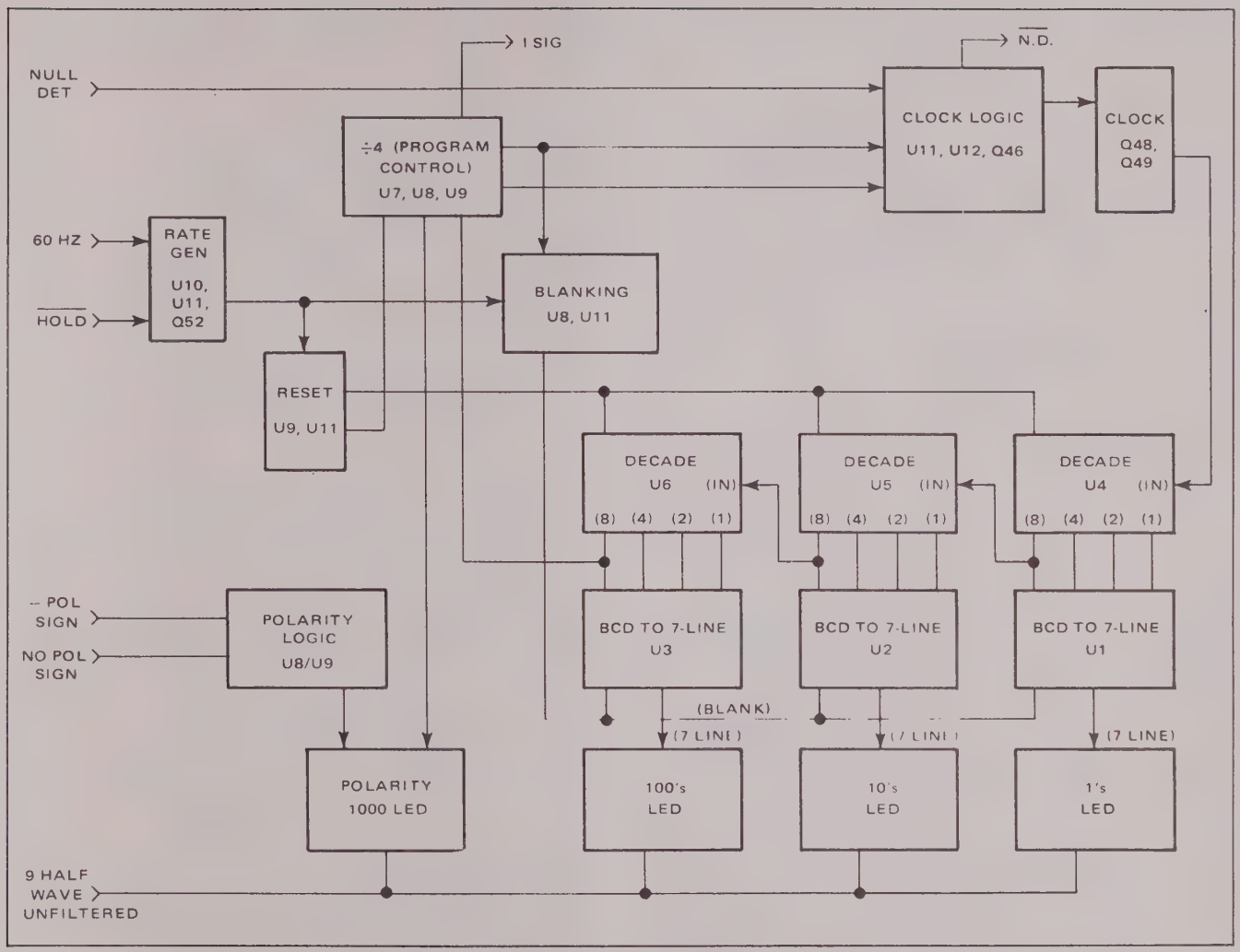


Figure 4.17 - Block Diagram – Digitizing and Display

to 0000. The clock runs during the entire integration cycle (T0 - T2) and at the start of a measurement, the counter is set to 1000. During the signal integration period (T0 - T1) the counter advances from 3000 until overflow at which time the signal integration period is terminated. The time required for the counter to advance from 3000 to 0000 (1000 clock cycles) determines the signal integration period. The counter continues from 0000 at the clock rate until the completion of the reference integration period (T1 - T2). At this time the clock is stopped. The position of the counter is converted from binary data to 7-segment data and displayed by the readout LEDs.

4.48 Rate Generator.

4.49 The rate generator controls the number of readings taken per second and synchronizes the start of the measurement period with the line frequency. Internal readings are taken at a rate of 6 per second; external readings (Option 51 only) can be taken up to 60 per second, maximum. A reading is initiated by the negative going edge produced by the rate generator.

4.50 The circuitry, shown simplified in figure 4.18, consists of a Schmitt trigger, a divide-by-ten circuit, and an inverter. The Schmitt trigger consisting of Q52, U11E converts a 25 volt, 60 Hz signal from the power supply to a 60 Hz square wave. The Schmitt output drives decode divider U10 wired to produce a symmetrical 6 Hz square wave output. Although only output A (pin 12) is used, outputs B, C, and D are shown in the table for reference. The $\overline{\text{HOLD}}$ from the Option 51 circuitry (when the instrument is so equipped) is inverted by U11D and controls one of the R9 inputs of U10. When $\overline{\text{HOLD}}$ line is at logic true, U10 is unaffected; when $\overline{\text{HOLD}}$ line is at logic false (Option 51 only) the U10 is reset to 0-0-1-1 and stays

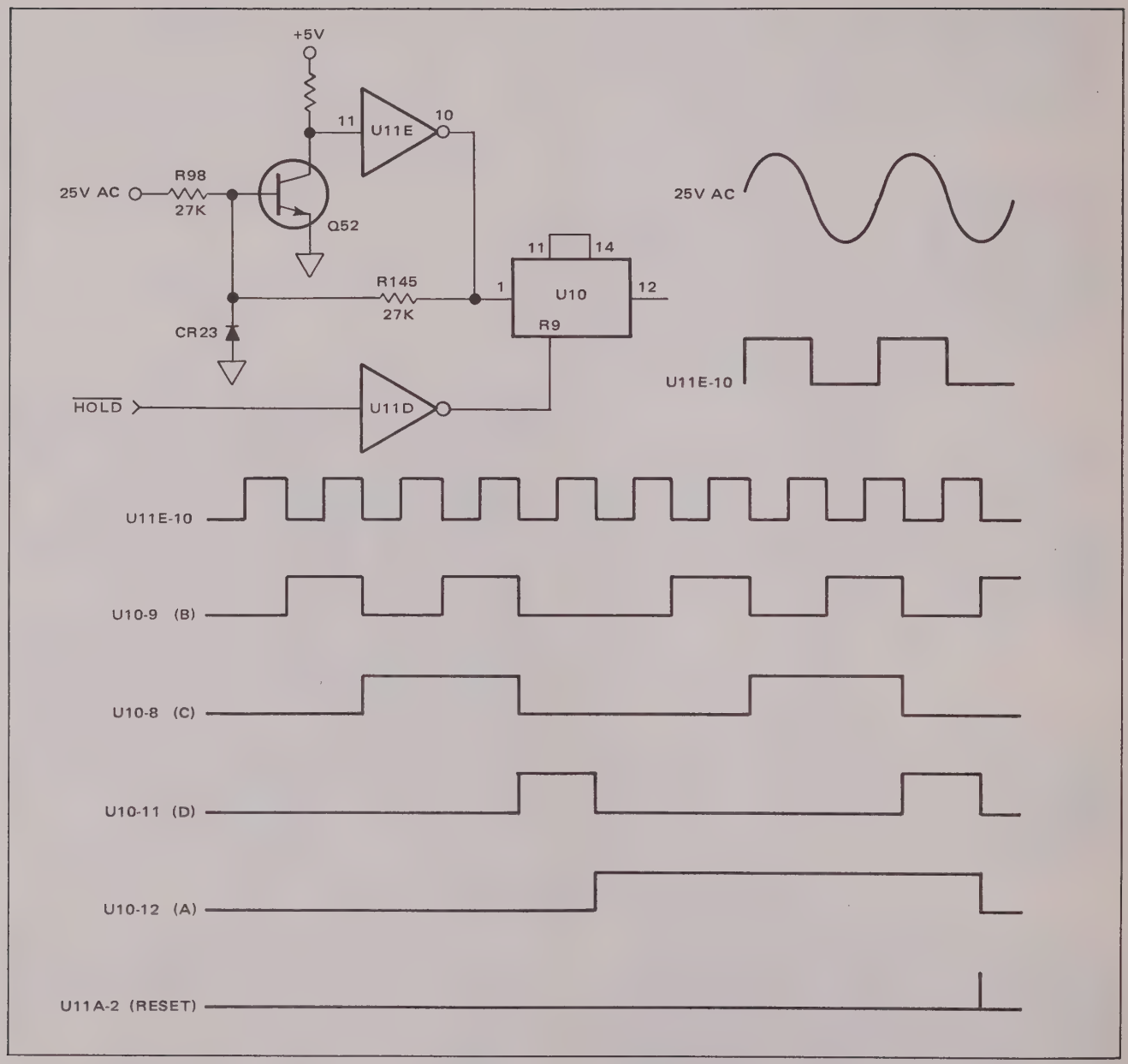


Figure 4.18 - Rate Generator

there as long as $\overline{\text{HOLD}}$ remains at logic false. When $\overline{\text{HOLD}}$ line goes to logic true, the next pulse from the Schmitt trigger advances U10 to 0-0-0-0, and a new measurement is started.

4.51 Reset.

4.52 The reset pulse sets the counter to 3000 and I SIGNAL circuitry of the Program Control to true. The reset consists of a differentiator circuit and two inverters (U11A and U9C). The differentiator converts the negative going edge of the rate generator output to a negative going pulse. The negative pulse is inverted by U11A to a positive pulse and resets the three binary counters U4, U5, and U6. The reset pulse is inverted by U9C and presets the 3000 bit F/Fs U7A and U7B. The $\overline{\text{RESET}}$ pulse is also used by the Option 51 circuitry.

4.53 ÷4/Program Control.

4.54 This circuitry produces the 1000 bit, generates the I SIG control signal for the integrator, controls the overload circuitry, and provides data for the clock logic. The circuitry, shown simplified in figure 4.19, consists of two

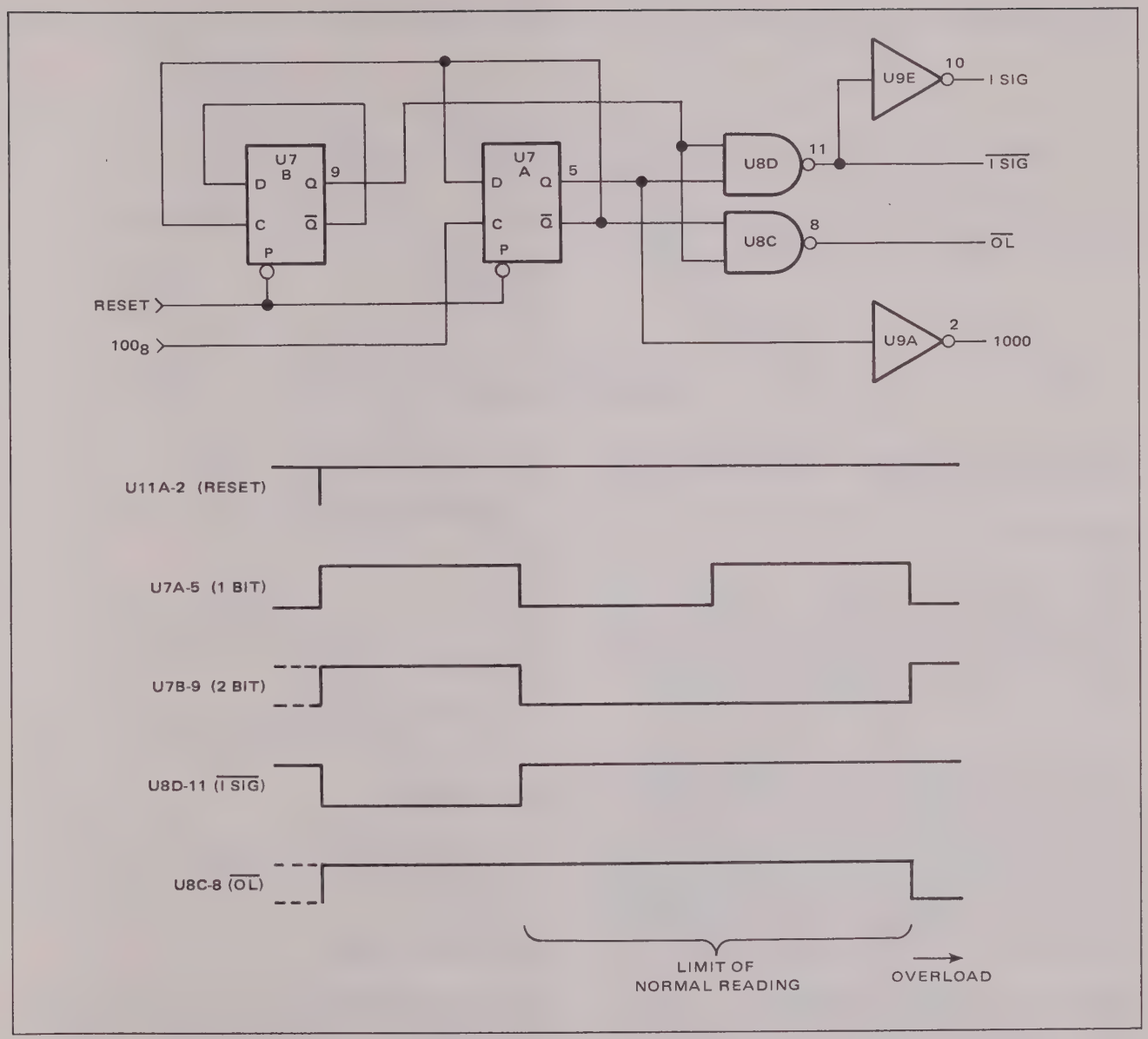


Figure 4.19 - ÷4 Program Control

D flip flops (U7A, U7B) wired in a ÷4 configuration, two NAND gates and two inverters. The ÷4 circuit is driven by the inverted 8 bit of the 100's decade and generates the output shown. The outputs are decoded by the NAND gates to generate $\overline{\text{I SIG}}$ and $\overline{\text{OL}}$. $\overline{\text{I SIG}}$ is inverted by U9E for use by the integrating circuitry.

4.55 Clock Logic.

4.56 The clock logic generates the control signal for starting and stopping the clock oscillator. Referring to the circuitry of figure 4.20, the basic circuitry consists of an R/S flip flop U12A, U12B driving inverter U11B. The output of U11B $\overline{\text{CLOCK ENABLE}}$, is set false and held false during the signal integration period by $\overline{\text{I SIG}}$ input to the flip flop. While $\overline{\text{CLOCK ENABLE}}$ is false, the clock is allowed to run. The $\overline{\text{CLOCK ENABLE}}$ line goes true when NULL DETECTOR line goes false or $\overline{\text{OL}}$ line goes false, either one of which resets the flip flop output false.

4.57 Clock.

4.58 The clock advances the counter and operates only during the measurement cycle. The clock is a gated free

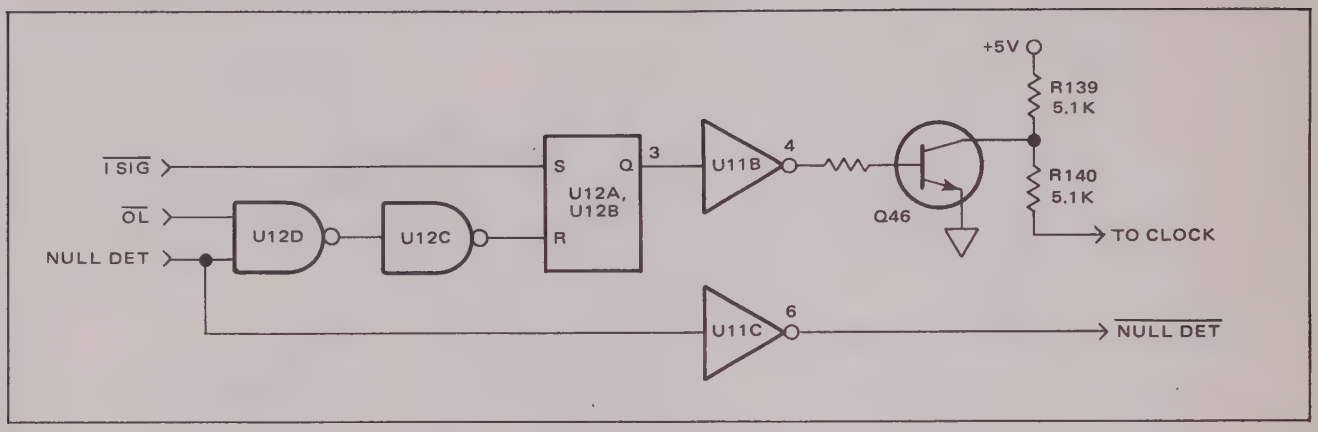


Figure 4.20 - Clock Logic

running multivibrator consisting of Q48, Q49 and is turned on and off by the control logic.

4.59 Counter.

4.60 The counter is a clock driven 3 decade plus over-range bit, BCD counter that determines the length of the Signal Integration period, measures the length of the Reference Integration period, and generates the value of the input signal in BCD form for the BCD to 7-line converter.

4.61 At the beginning of a measurement cycle, the counter is set to 3000 and the clock is started. The signal integration period is begun and the counter advances from 3000 to 3999 and overflows to 0000. When the counter overflows, the Signal Integration period terminates and the Reference Integration period begins. The counter continues to count until the Null Detector line goes false indicating the completion of the Reference Integration period or the counter again overflows indicating an overload condition.

4.62 BCD to 7-Segment Converters.

4.63 The BCD to 7-segment converters transform the setting of the counter from BCD form to 7-segment form for driving the LED readouts of the 1's, 10's, and 100's decades.

4.64 Overload.

4.65 The overload causes the display to blank at a 6 per second rate when the instrument's input signal exceeds the maximum allowable for the function and range selected. The circuitry consists of inverter U11F and NAND gate U8B. The blanking is achieved by enabling the 6 Hz signal from the rate generator to reach the blanking inputs of the BCD to 7-segment converters. Gate U8B is controlled by the inverted $\overline{OL}$ output of the Program Control circuitry.

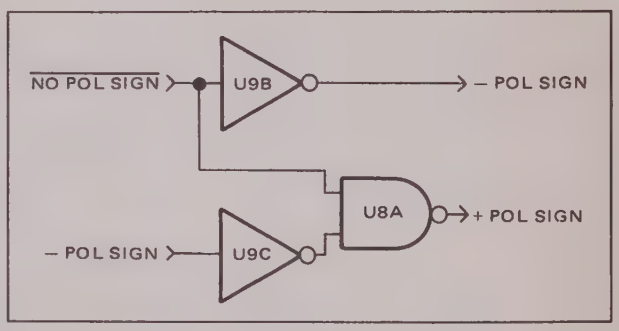


Figure 4.21 - Polarity Logic

4.66 Polarity.

4.67 The polarity circuit controls the polarity portion of the 1000/Polarity LED. The circuitry is shown in figure 4.21.

4.68 Power Supply.

4.69 TRANSFORMER.

4.70 The power supply is provided with a double shield, dual primary transformer. The primaries can be connected in parallel or series for 115 or 230 volt operation by the placement of jumpers on the main circuit board. Two center tapped secondaries provide 9-0-9 volts and 25-0-25 volts.

4.71 SUPPLY OUTPUTS.

4.72 The power supply circuitry is shown in simplified form in figure 4.22. The outputs and circuitry used to generate each are described below:

+9V Half Wave. This signal is taken from diode CR26 and is used to power the LED displays.

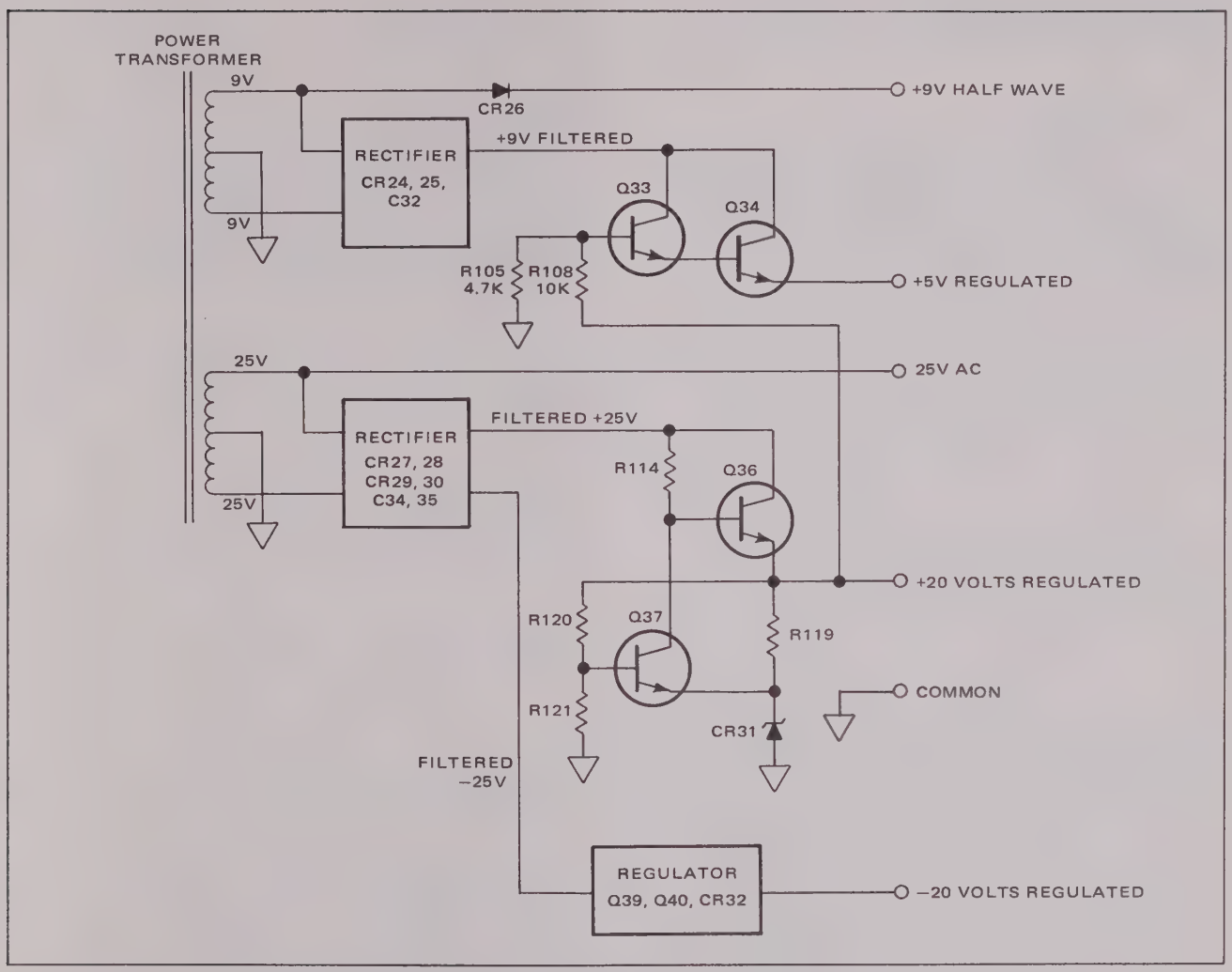


Figure 4.22 - Power Supply Circuitry

+5 Volt Regulated. A +9 volt full wave filtered voltage powers the collectors of Darlington coupled transistors Q33, Q34. The reference is a voltage divided portion of the +20 volt regulated supply. The +5 volt regulated supply is used by the Integrated circuits of the instrument (grounded portion of Option 51 excepted).

25 Volts AC. The 25 volt AC signal is taken from one side of the center tapped 25-0-25 secondary winding and is in-phase with the +9V half wave output. The 25 volt AC signal is used to synchronize the Rate Generator.

+20 Volts Regulated. The circuitry consists of power transistor Q36, connected in an emitter follower configuration driven by the collector of common emitter coupled transistor Q37. The output of the supply is taken from the emitter of Q36 which also supplies current to reference zener CR31 (7.5V) and voltage divider R120/R121. The emitter of Q37 is referenced to the zener voltage and the base of Q37 monitors the output of the voltage divider providing the required regulation. A plus 25 volts full wave filtered voltage level is supplied to the collector of Q36 and collector resistor R114.

−20 Volts Regulated. This circuit consists of transistors Q39 and Q40 and zener CR32 and operates in the same manner as the +20 volt regulated supply. Both supplies

provide power levels for use by the analog circuitry of the instrument.

4.73 Display Board.

4.74 The display board contains the LED displays and necessary current limiting resistors all mounted on a single circuit board and mounted in connector J1 on the main circuit board.

4.75 Fuse Board.

4.76 The fuse board is a printed circuit subassembly mounted to the back of the function switch. The fuse board contains a 2 Amp fuse wired in series between the Ohms/Amps terminal of the instrument and unprotected portions of the measurement circuitry. Also connected on the circuit side of the fuse is a diode clamp network designed to conduct at slightly more than ± 2 volts.

SECTION 5 CALIBRATION

5.1 INTRODUCTION

5.2 This calibration procedure is designed to assure the Series 3800B DMM operates within its specifications. Calibration points are shown in figure 5.1 and the procedure begins on table 5.1. The calibration steps in each procedure rely on the adjusted accuracy of the preceding step, therefore care must be taken to make each adjustment in the order that it appears in this procedure.

5.3 EQUIPMENT REQUIRED

5.4 The following equipment, or an acceptable equivalent, is required for DMM calibration and is listed in order of use. The test equipment specification listed are recommended for calibration.

5.5 TOOLS REQUIRED FOR CALIBRATION

a. An insulated blade type calibration tool.

b. A No. 1 Phillips screwdriver.

5.6 PREPARATION FOR CALIBRATION

a. Place instrument on flat level surface with bail extended toward the front of the instrument. Remove the two screws at the top of the back panel and the two screws at the top of the side panels. Lift the top cover straight up to avoid bending the decorative metallic strips on the sides of the instrument. All calibration points are accessible with the top cover removed.

b. Set the DMM controls as follows:

Function	Volts DC
Range:	200 mV
Input:	Shorted (Red to Black)

c. Set the ON-OFF switch to the ON position and allow 30 minutes for warmup.

5.7 Basic DC Calibration

a. A precision DC voltage standard variable from 0 to 1000 volts having a resolution of 100 microvolts at 10 volts and an accuracy of .003%. For example, the FLUKE 332A.

b. A precision decade divider having an input resistance of 10 Kohms and an output resistance of 5 Kohms maximum, and an accuracy of .005%. For example, the ESI MODEL RV622A.

5.8 AC Calibration

a. An AC laboratory power source, variable from 0 to 500 volts RMS and 50 Hz to 100 kHz, having a resolution better than 100 PPM, harmonic distortion of .1%. For example, the HP 745/746.

b. An AC/DC laboratory transfer standard (for calibration of the AC source) having an accuracy of .05%. For example, the HOLT MODEL 6 thermal transfer voltmeter.

5.9 Milliamps and Microamps Calibration

a. A power supply with the capability of delivering 1000 mA in the current mode. For example, the SORRENSON QRB 30-1.

b. A current shunt resistor capable of 1 amp to standardize the current source. For example, 10 volts across 10 ohms.

5.10 Ohms Calibration

a. Standard resistors: 100 ohms, 1 kohm, 100 Kohm, and 1 Mohm with a value known to .005% and a 10 Mohm with a value known to .01%. For example, the ESI SR-1 series standard resistors.

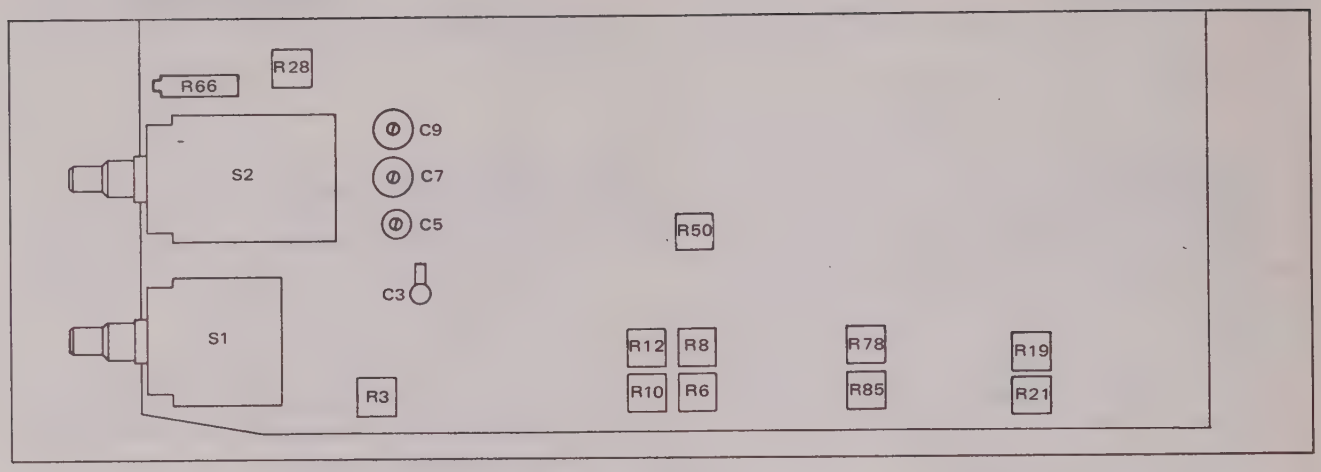


Figure 5.1 - Calibration Points

Table 5.1 - DC Calibration

FUNCTION	RANGE	INPUT	ADJUST	DISPLAY	REMARKS
VDC	200 mVDC	OV	R66	00.0	Polarity Indicators flashing
VDC	2 VDC	+1.190	R85	+1.190	Plus full scale adjust
VDC	2 VDC	-1.190	R78	-1.190	Minus full scale adjust
VDC	200 mVDC	+119.0mV	R28	+119.0mV	Millivolts full scale adjust
VDC	200 mVDC	-119.0mV	–	-119.0mV	±1 digit
VDC	20 VDC	+11.90V	R6	+11.90V	10 volt full scale adjust
VDC	20 VDC	-11.90V		-11.90V	10 volt full scale adjust
VDC	200 VDC	+119.0V	R8	+119.0V	100 volt full scale adjust
VDC	200 VDC	-119.0V		-119.0V	100 volt full scale adjust

Table 5.2 - AC Calibration

FUNCTION	RANGE	INPUT	ADJUST	DISPLAY	REMARKS
VAC	20 VAC	11.90VRMS	R50	11.90VRMS	@ 400 Hz
VAC	2000 VAC	500.0VRMS	C3	500.0VRMS	±5 digits @ 20 kHz
VAC	2 VAC	1.190VRMS	C5	1.190VRMS	±5 digits @ 20 kHz
VAC	20 VAC	11.90VRMS	C7	11.90VRMS	±5 digits @ 20 kHz
VAC	200 VAC	119.0VRMS	C9	119.0VRMS	±5 digits @ 20 kHz

Table 5.3 - DC Current Calibration

FUNCTION	RANGE	INPUT	ADJUST	DISPLAY	REMARKS
MADC	2000 mADC	+1190 mA	R3	+1190 mADC	Milliamp full scale adjust
MADC	2000 mADC	-1190 mA	–	-1190 mADC	± 2 digits
MADC	200 mADC	+100.0 mA	–	+100.0 mADC	± 2 digits
MADC	200 mADC	-100.0 mA	–	-100.0 mADC	± 2 digits
MADC	20 mADC	+10.00 mA	–	+10.00 mADC	± 2 digits
MADC	20 mADC	-10.00 mA	–	-10.00 mADC	± 2 digits
MADC	2 mADC	+1.000 mA	–	+1.000 mADC	± 2 digits
MADC	2 mADC	-1.000 mA	–	-1.000 mADC	± 2 digits
µADC	200 µADC	+100.0 µA	–	+100.0 µADC	± 2 digits
µADC	200 µADC	-100.0 µA	–	-100.0 µADC	± 2 digits
µADC	20 µADC	+10.00 µA	–	+10.00 µADC	± 2 digits
µADC	20 µADC	-10.00 µA	–	-10.00 µADC	± 2 digits

Table 5.4 - Resistance Calibration

FUNCTION	RANGE	INPUT	ADJUST	DISPLAY	REMARKS
Ohms	20 Kohm	10 Kohm	R19	10.00	± 1 Digit
Ohms	20 Mohm	10 Mohm	R21	10.00	± 1 Digit
Ohms	2 Kohm	1 Kohm	R10	1.000	± 1 Digit
Ohms	200 Ohm	100 Ohm	R12	100.0*	± 1 Digit *(Short input leads, note digits offset, and adjust the display for the standard plus the offset)
Ohms	2000 Kohm	1 Mohm	–	1000	± 1 Digit
Ohms	200 Kohm	100 Kohm	–	100.0	± 1 Digit

Table 5.5 - 2000 Volt Range Check

FUNCTION	RANGE	INPUT	ADJUST	DISPLAY	REMARKS
VDC	2000	+1000	–	+1000	± 4 digits
VDC	2000	-1000	–	-1000	± 4 digits

SECTION 6 DRAWINGS

Figure	Title	Page
6.1	Layout, Digital Multimeter (400972)	6-2
6.2	Layout, Module (403860)	6-3
6.3	Layout, Main Logic (403863)	6-4
6.4	Schematic, Main Logic	6-5/6-6/6-7
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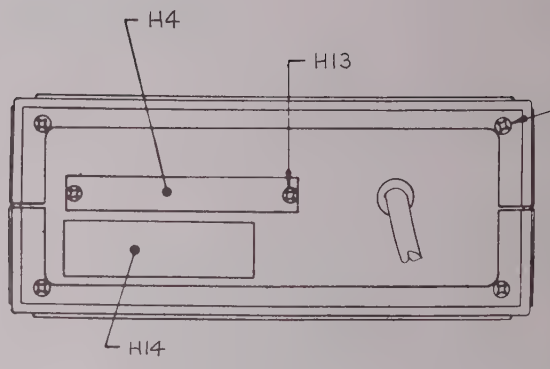
6.6	Layout, Display (403858)	6-9
6.7	Schematic, Display	6-9
6.8	Layout, Fuse Board (403859)	6-10
6.9	Schematic, Fuse Board	6-10
6.10	Assembly, Data Output Option 51 (400973)	6-11
6.11	Layout, Data Output (403862)	6-12
6.12	Schematic, Data Output	6-13



REAR VIEW

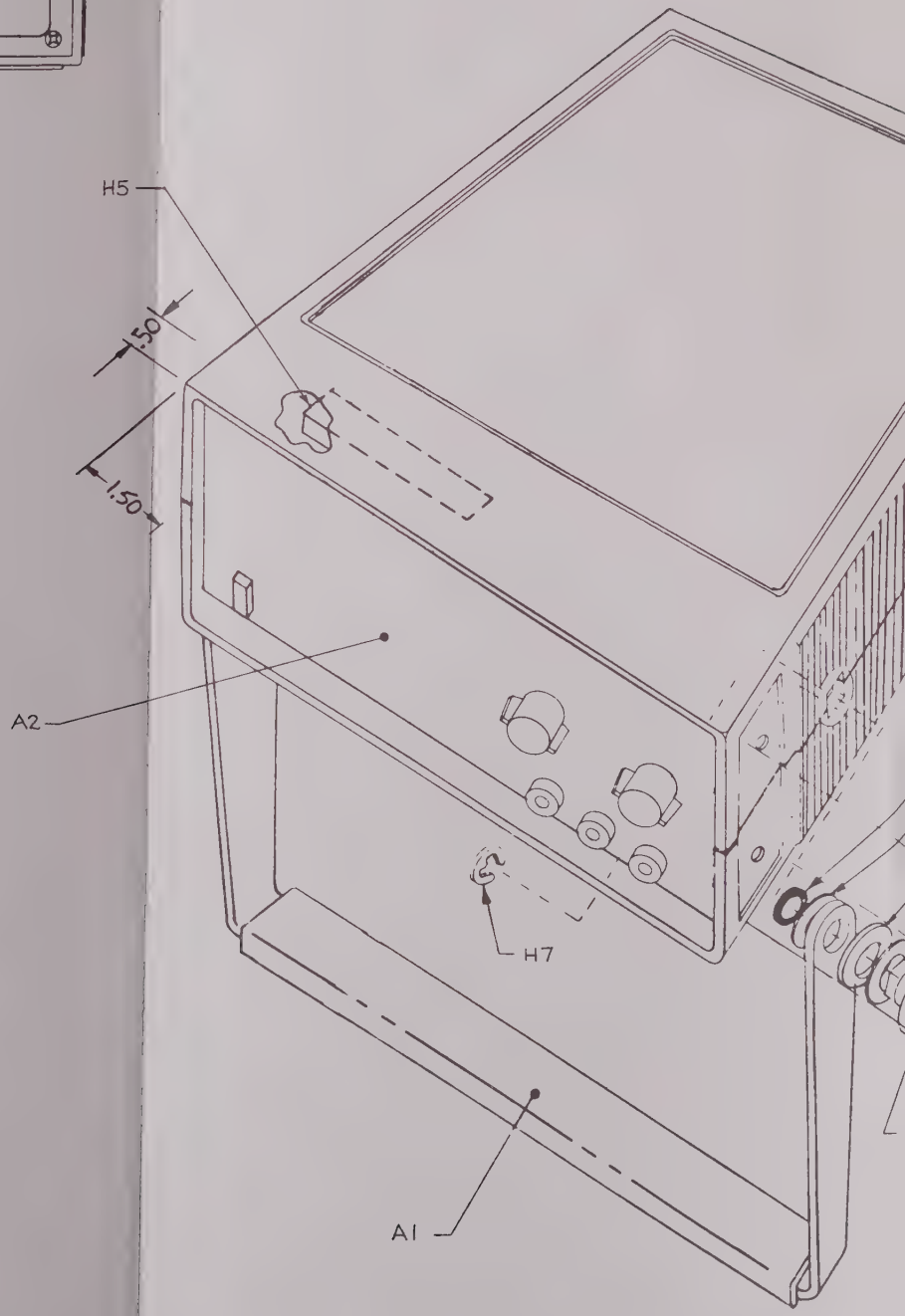
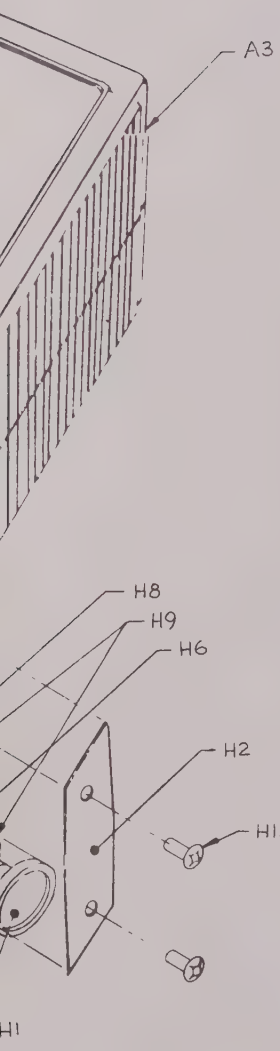
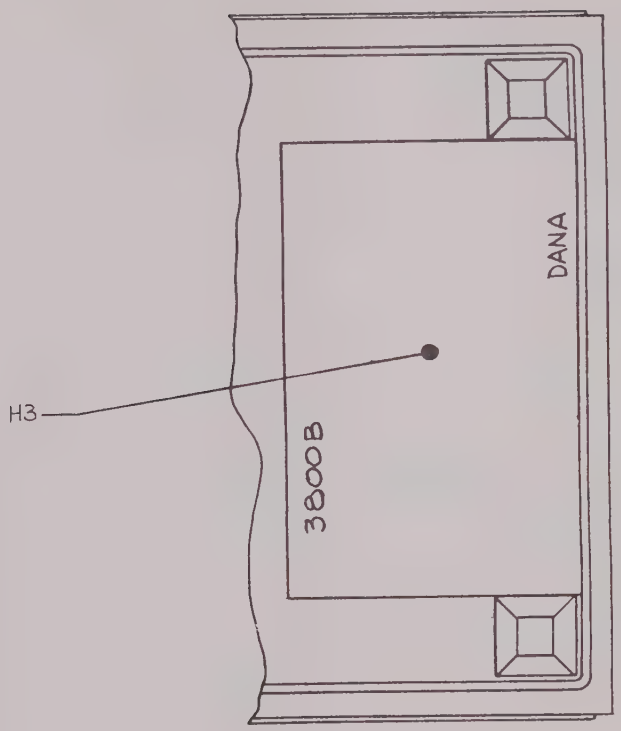
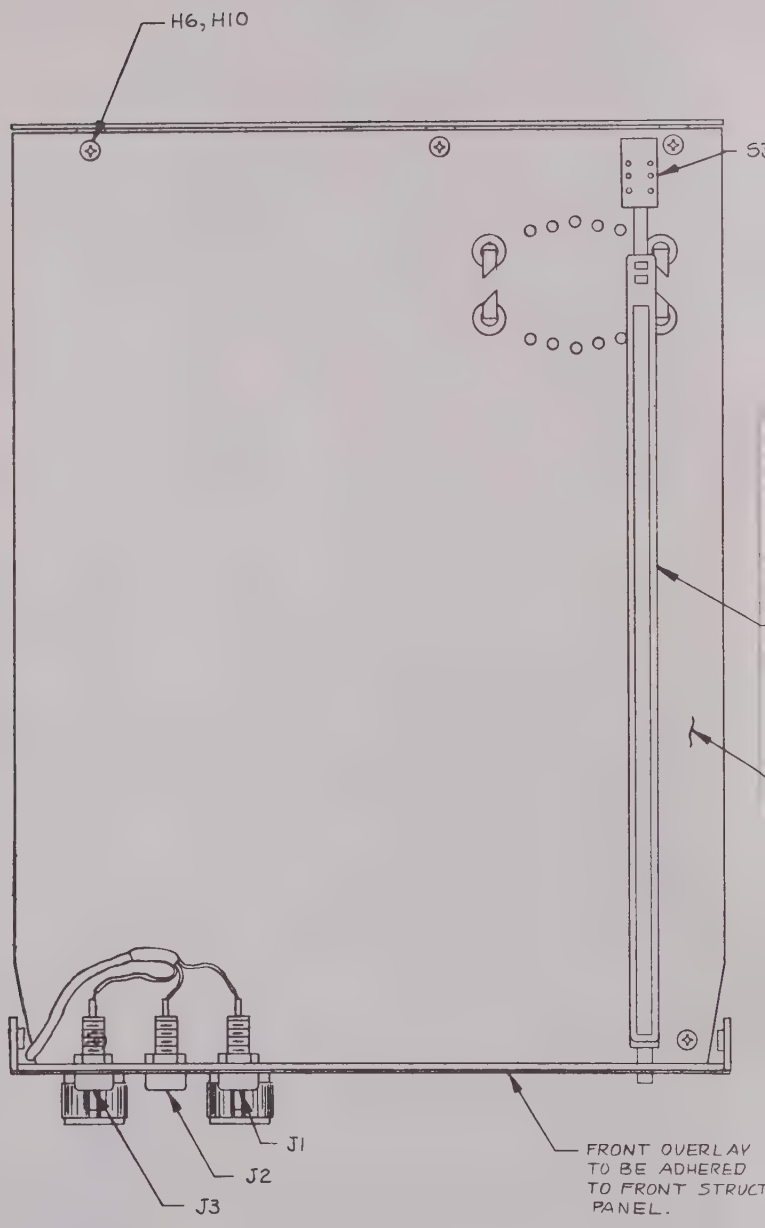


Figure 6.1 - Layout, Digital Multimeter (400972)


A3
H8
H9
H6
H2
H12
H1


H3
DANA
3800B


H6, H10
J1
J2
J3
FRONT OVERLAY
TO BE ADHERED
TO FRONT STRUCT
PANEL.

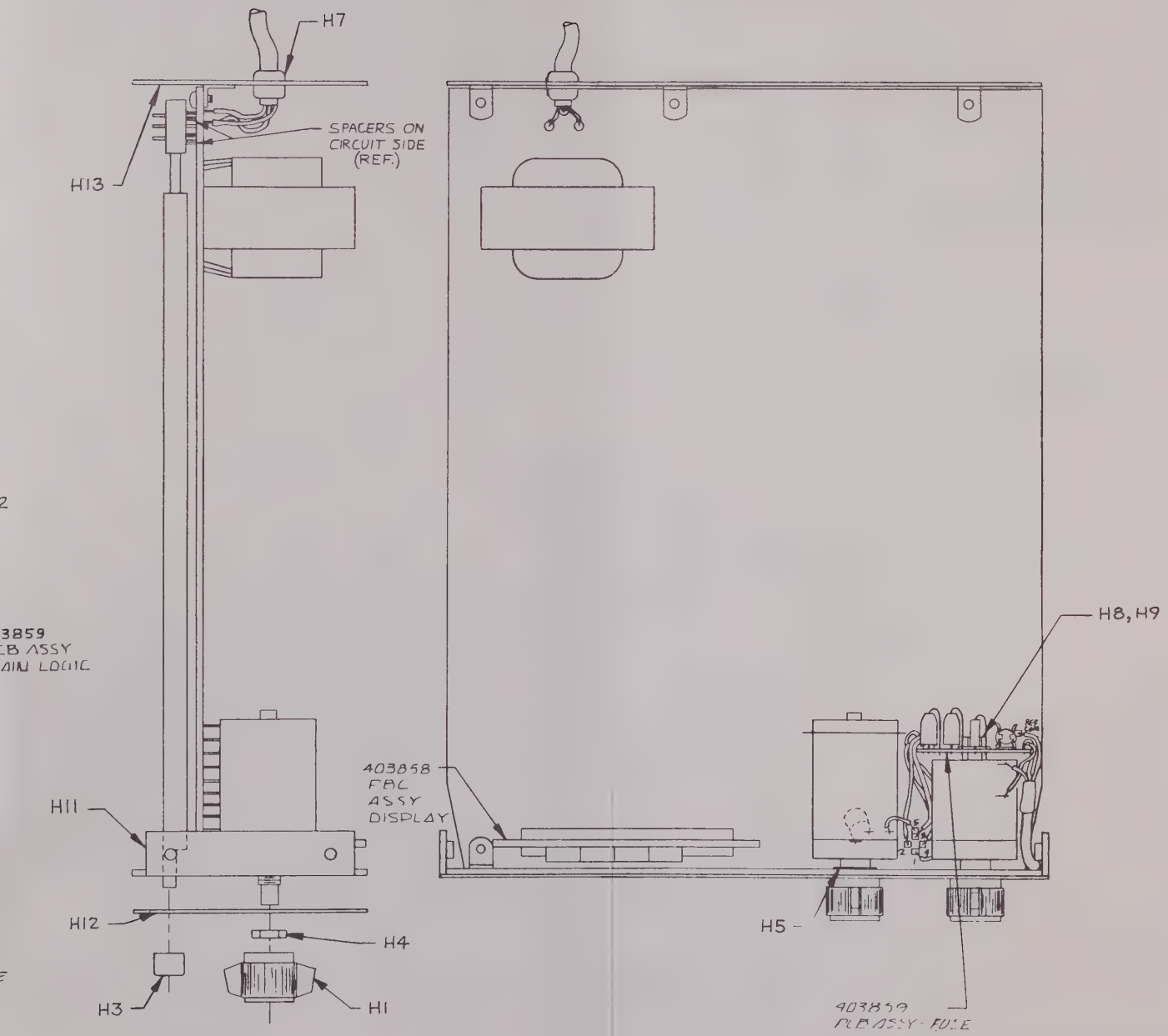
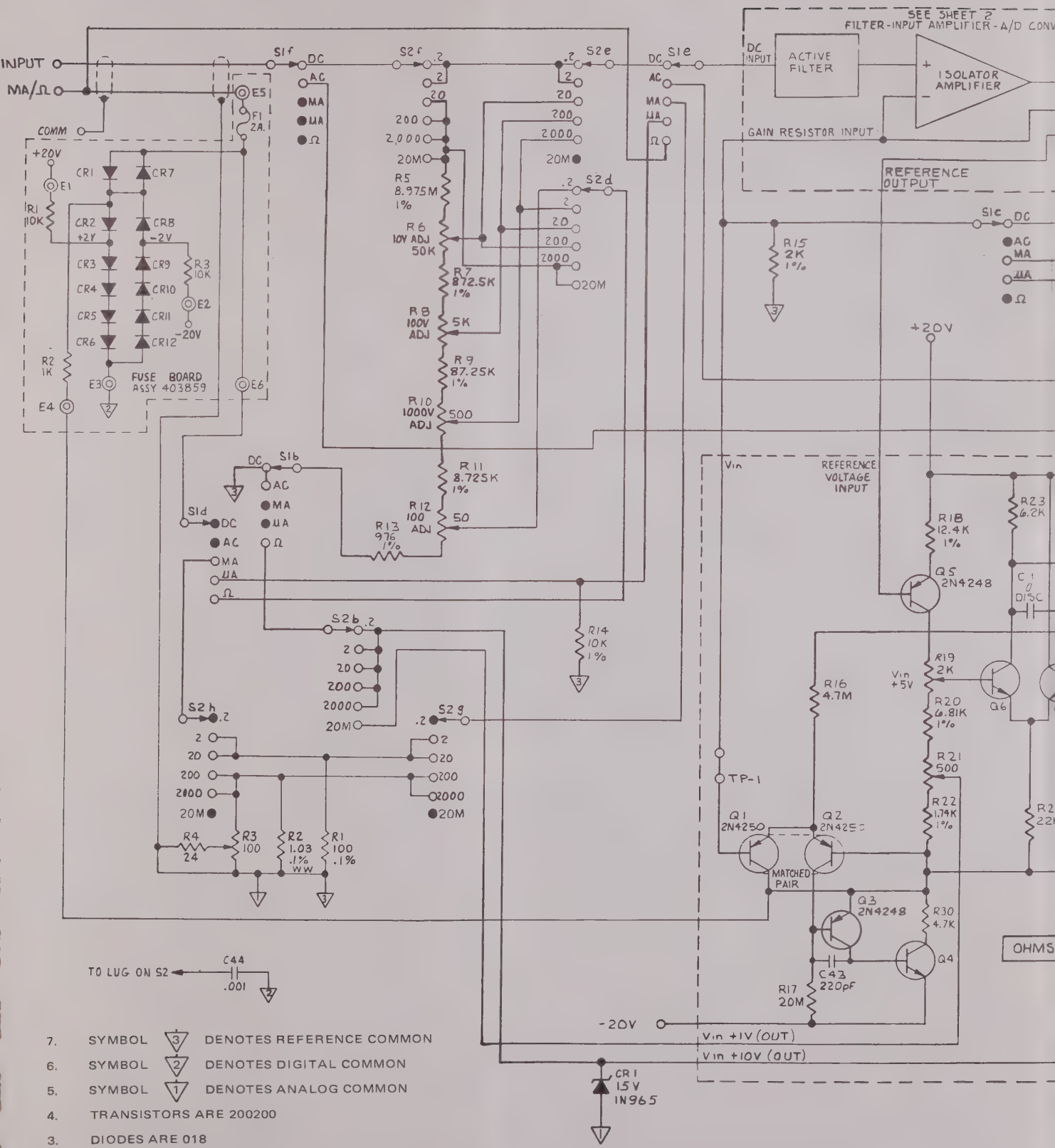


Figure 6.2 - Layout, Module (403860)



7. SYMBOL (3) DENOTES REFERENCE COMMON
6. SYMBOL (2) DENOTES DIGITAL COMMON
5. SYMBOL (1) DENOTES ANALOG COMMON
4. TRANSISTORS ARE 200200
3. DIODES ARE 018
2. CAPACITORS ARE IN μF
1. RESISTORS ARE IN OHMS ±5% 1/4W

NOTES: UNLESS OTHERWISE SPECIFIED

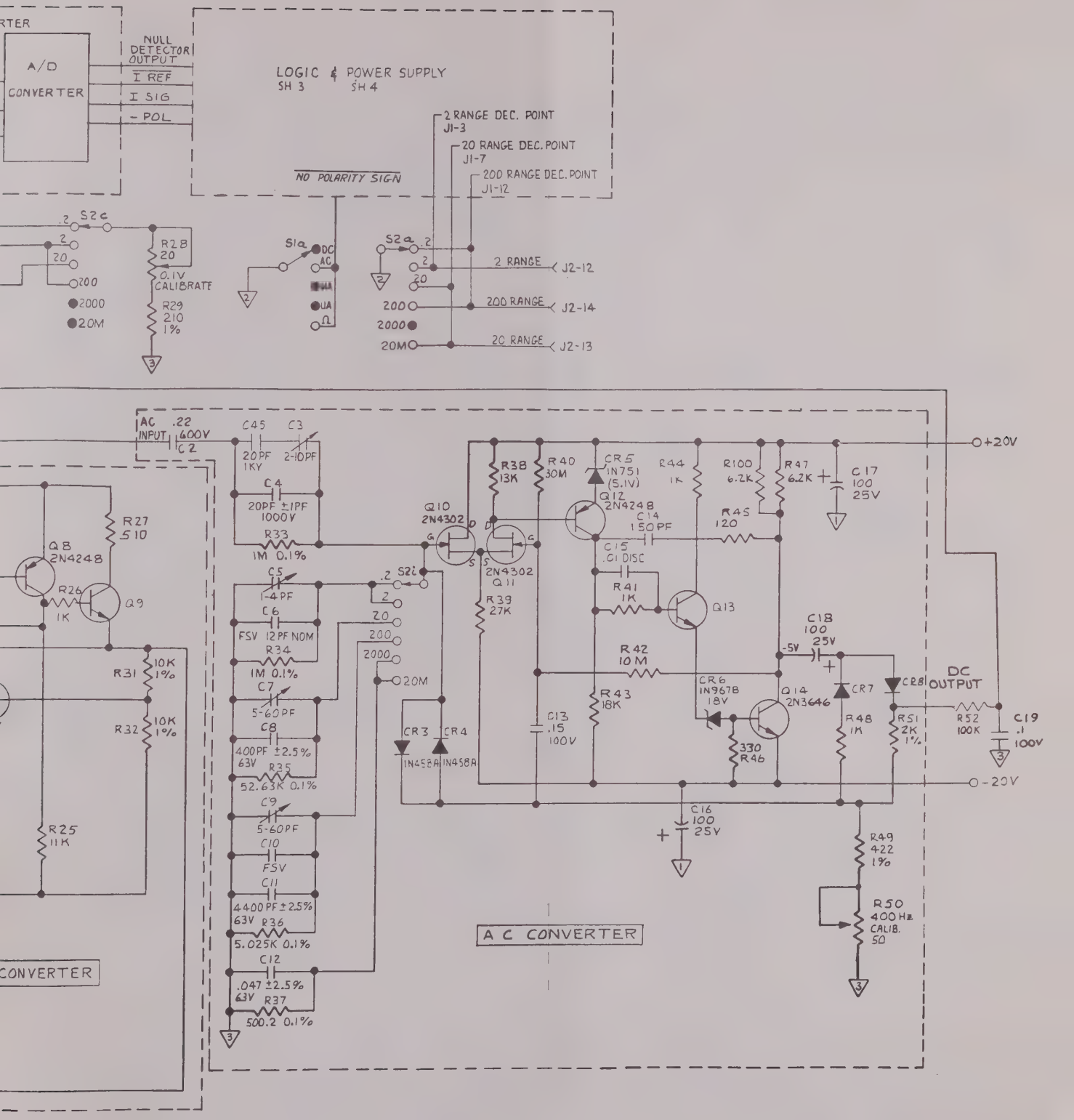
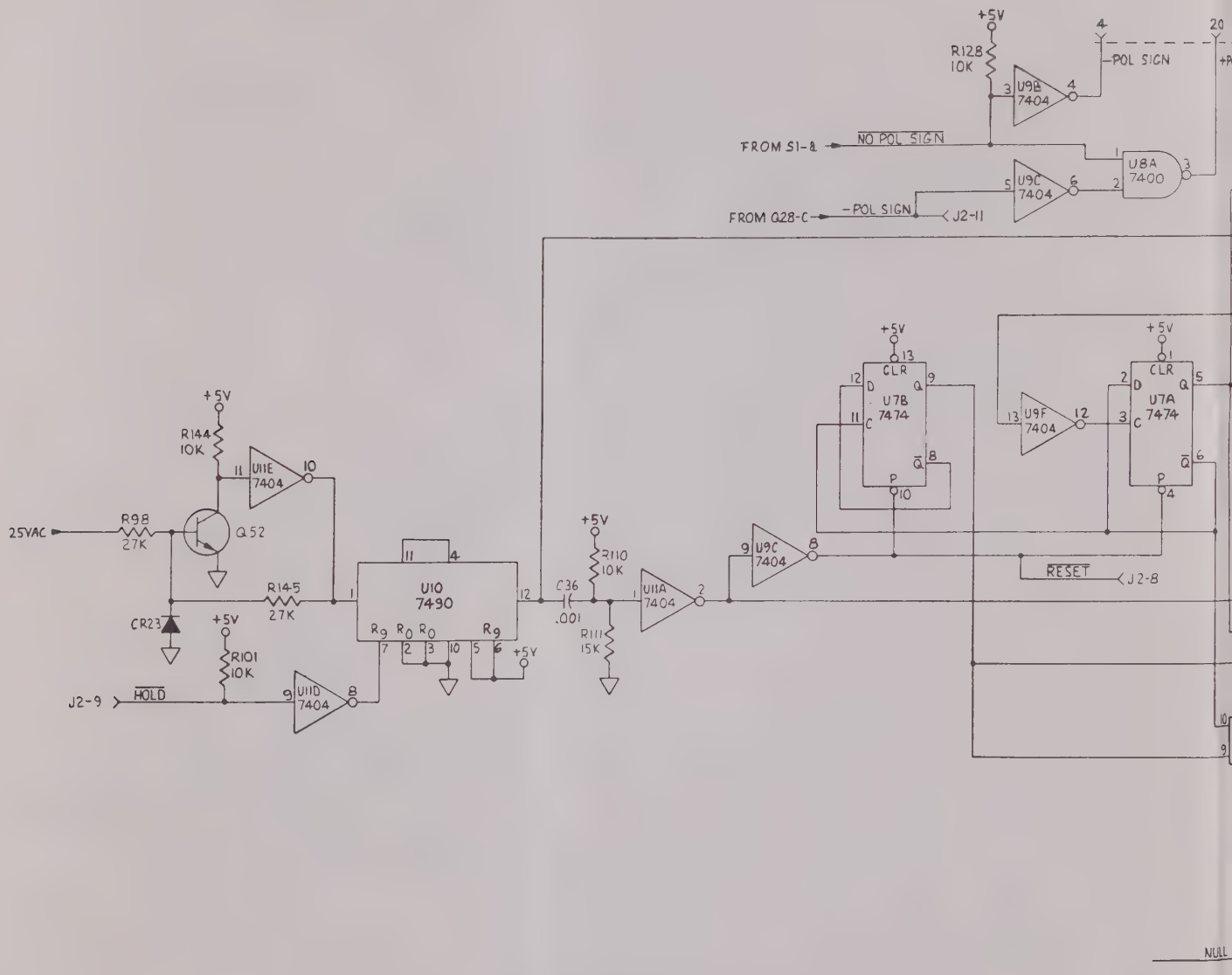


Figure 6.4 - Schematic, Main Logic


+5V
R128
10K
U9B
7404
4
20
-POL SIGN
FROM S1-8
NO POL SIGN
U8A
7400
U9C
7404
FROM Q28-C
-POL SIGN
J2-11
+5V
R144
10K
U11E
7404
25VAC
R98
27K
Q52
R145
27K
CR23
+5V
R101
10K
J2-9
HOLD
U11D
7404
U10
7490
R9 R0 R0 R9
+5V
C36
.001
+5V
R110
10K
R111
15K
U11A
7404
U9C
7404
+5V
U7B
7474
CLR
D
C
P
Q
+5V
U9F
7404
+5V
U7A
7474
CLR
D
C
P
Q
RESET
J2-8

NULL

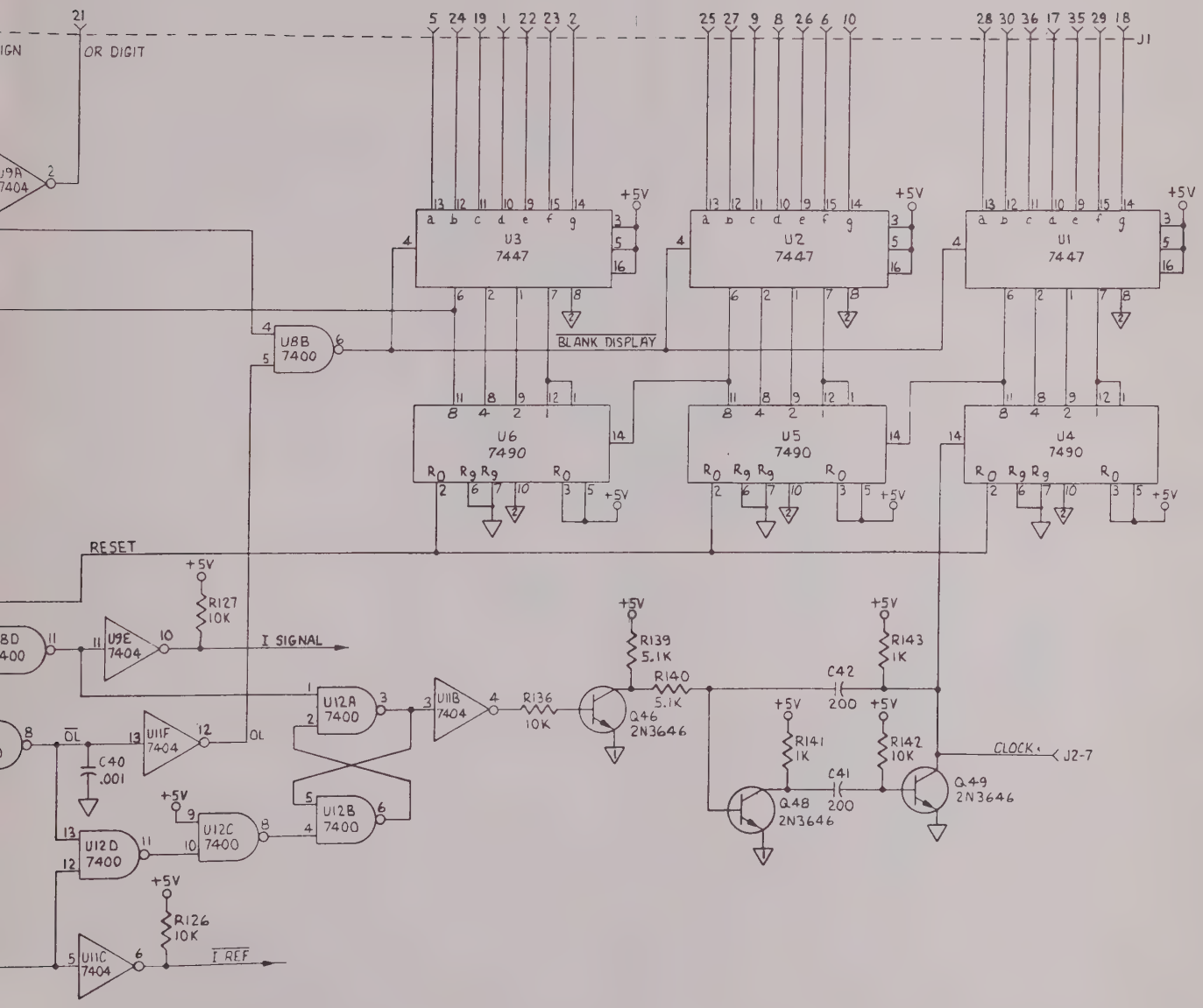
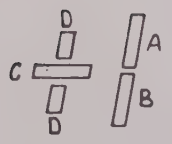
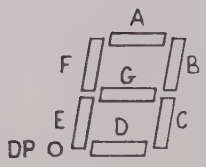
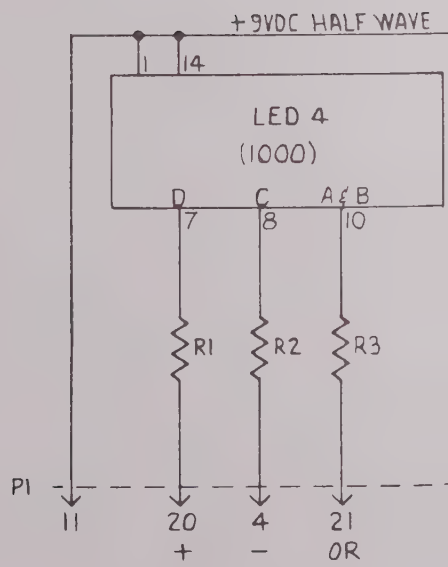


Figure 6.4 - Schematic, Main Logic (continued)


D
C
A
B
D


A
F
B
G
E
D
C
DP


+9VDC HALF WAVE
1
14
LED 4
(1000)
D
C
A & B
7
8
10
R1
R2
R3
P1
11
20
+
4
−
21
OR

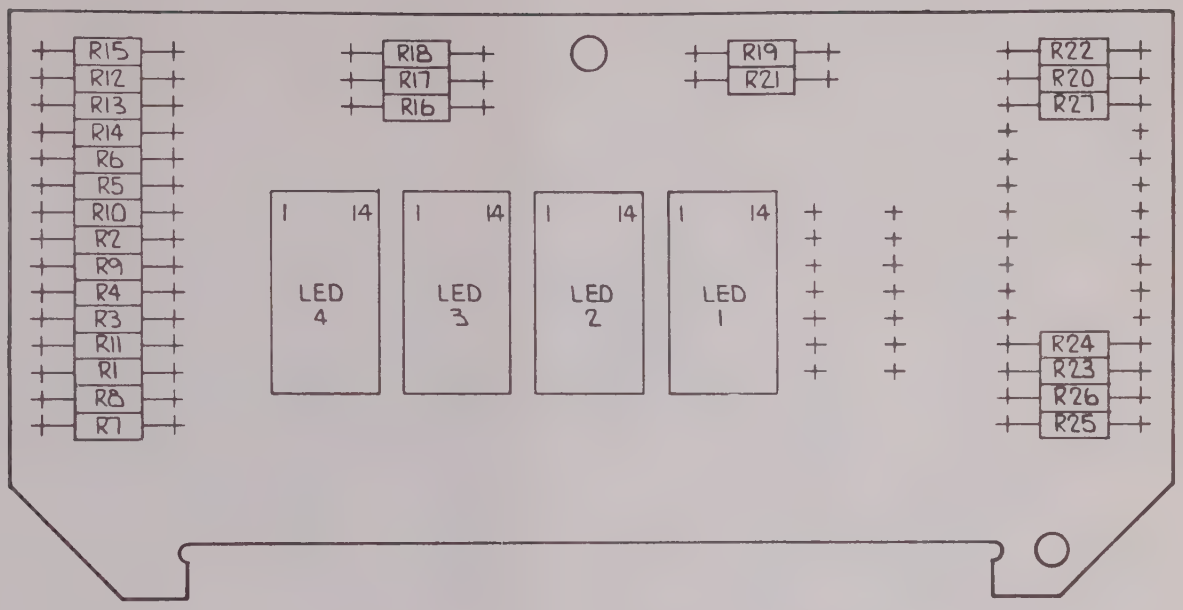


Figure 6.6 - Layout, Display (403858)

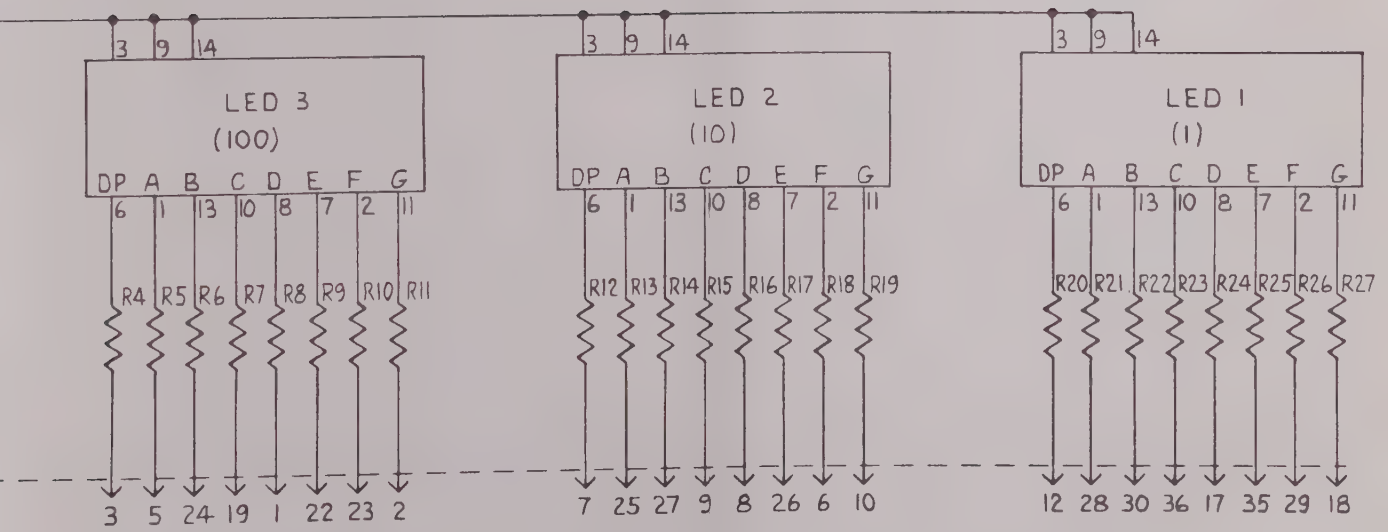
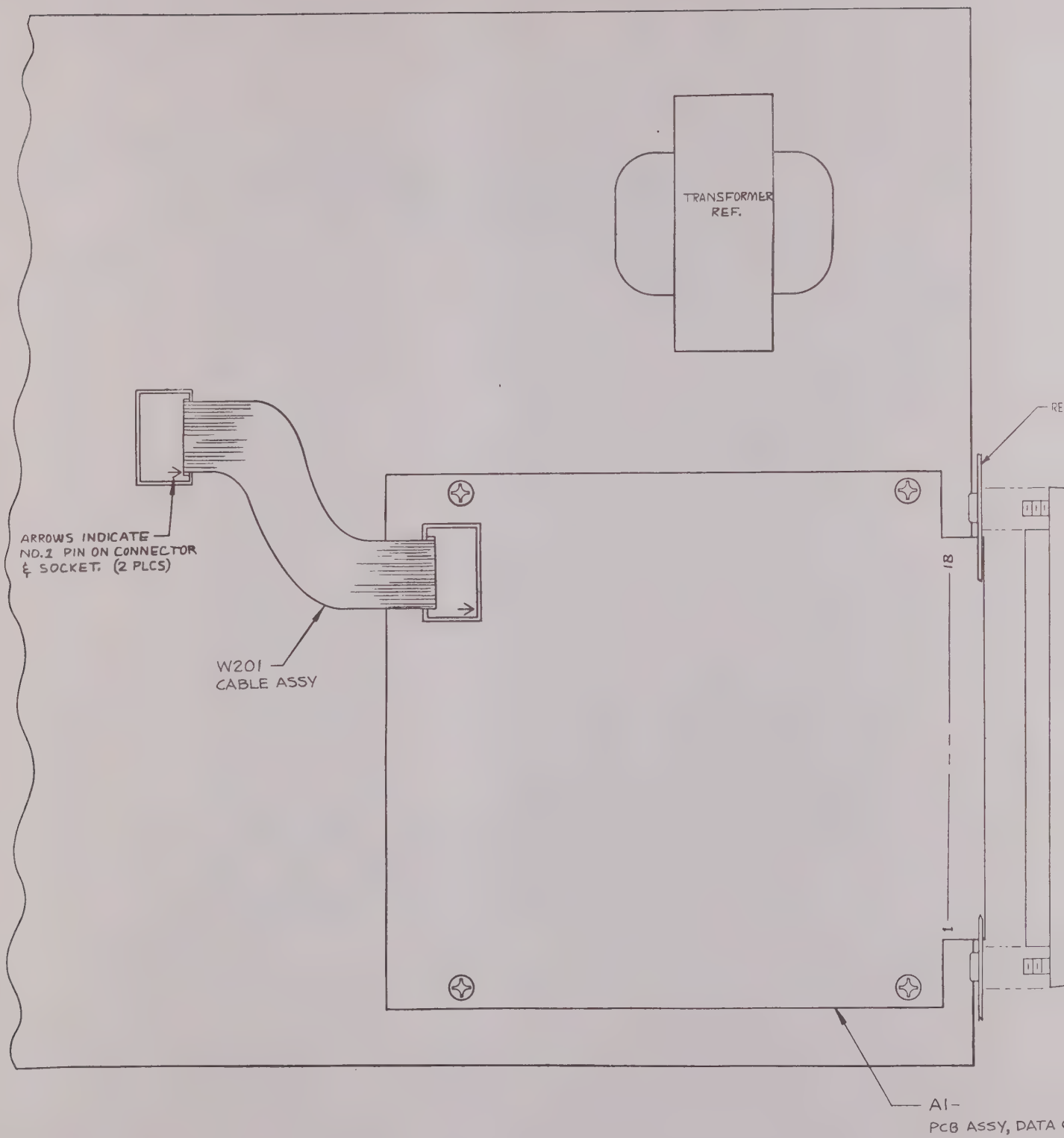


Figure 6.7 - Schematic, Display


TRANSFORMER
REF.
ARROWS INDICATE
NO.1 PIN ON CONNECTOR
& SOCKET. (2 PLCS)
W201
CABLE ASSY
18
1
A1-
PCB ASSY, DATA

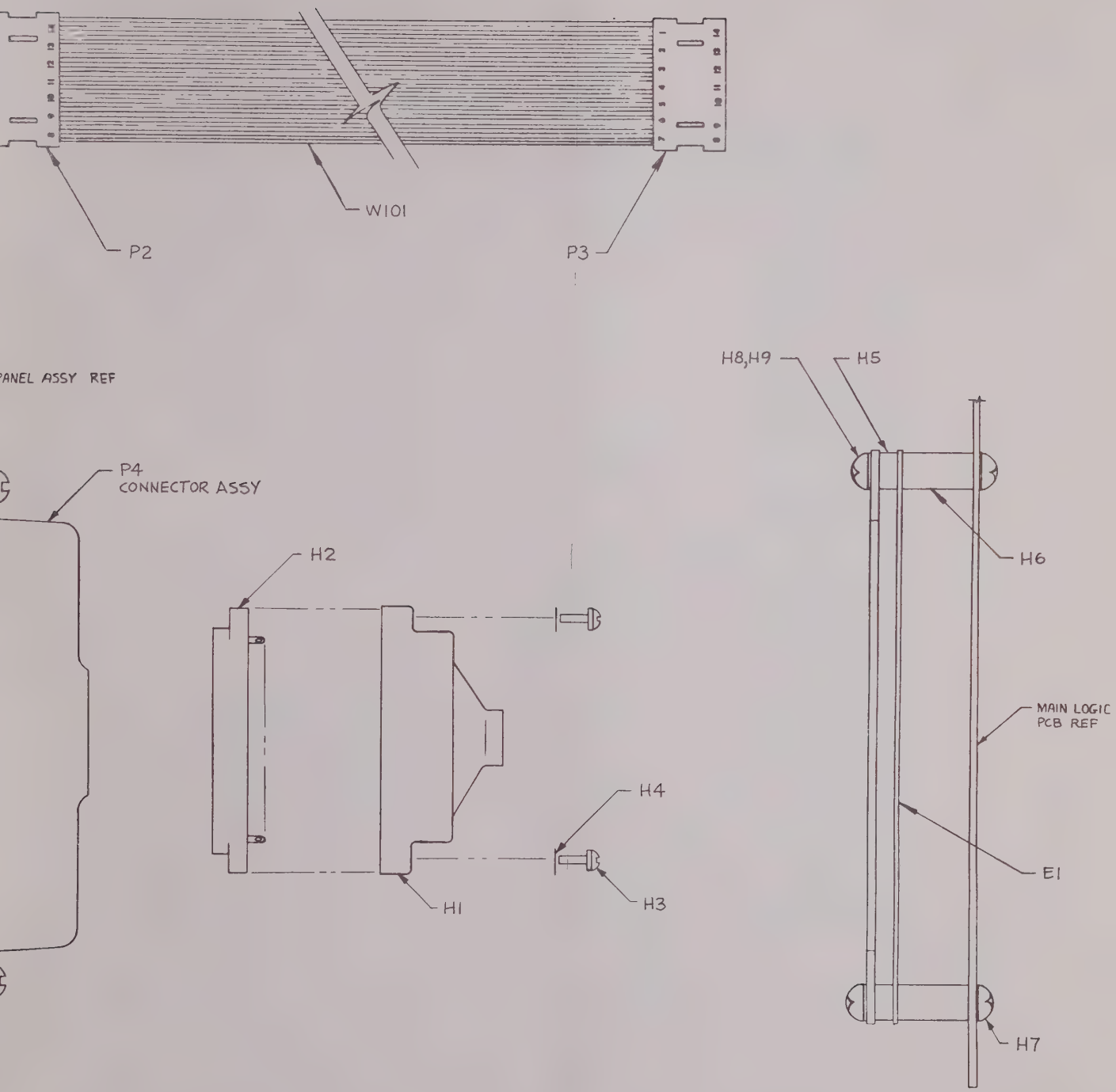
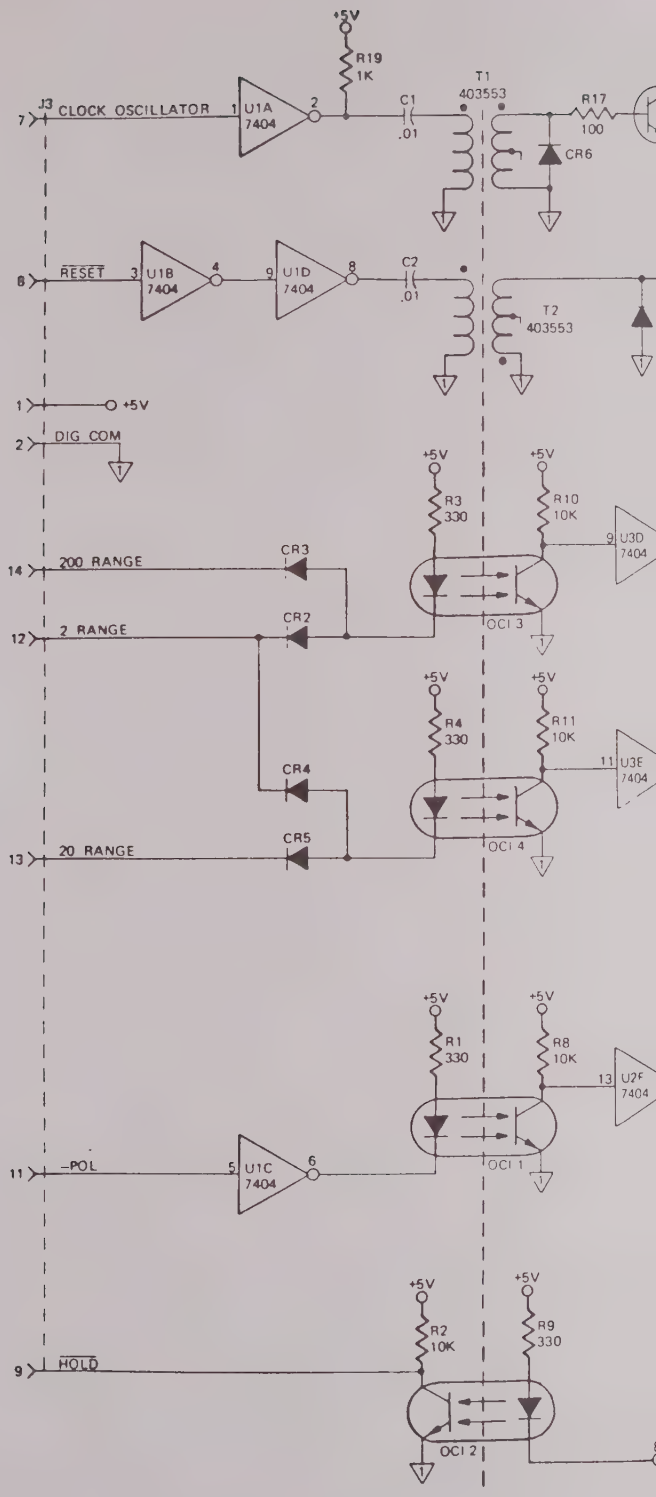


Figure 6.10 - Assembly, Data Output Option 51 (400973)



3. DIODES ARE 018

2. CAPACITORS ARE IN μF

1. RESISTORS ARE IN OHMS ±5%, 1/4W

NOTES: UNLESS OTHERWISE SPECIFIED

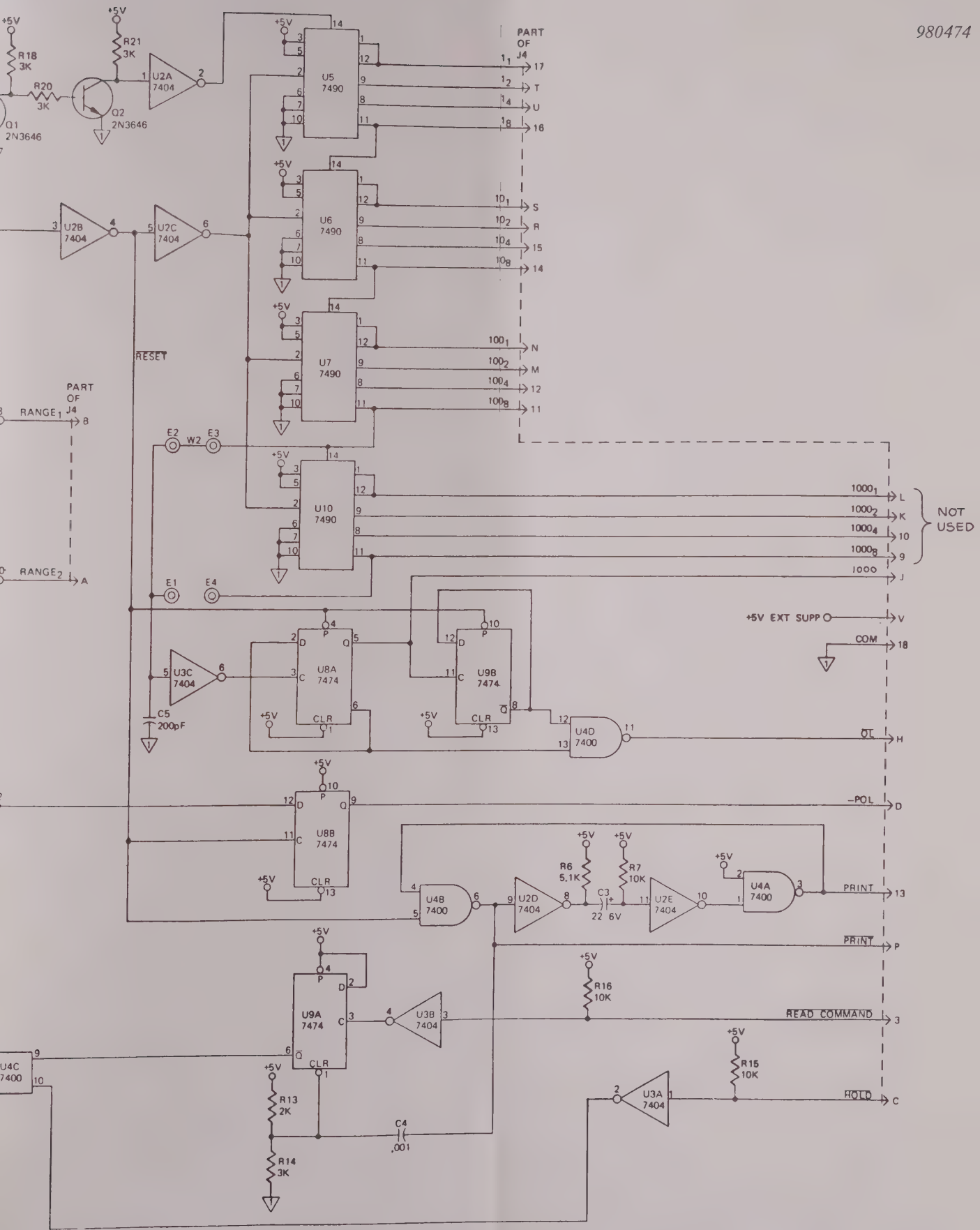


Figure 6.12 - Schematic, Data Output

SECTION 7 PARTS LIST

7.1 This section contains lists of replaceable parts arranged in the order of the following subassemblies:

Page

Digital Multimeter 7-3
Module – DMM 7-4
Main Logic 7-5
Display 7-12
Fuse Board 7-13
Data Output, Option 51 7-14
Data Output 7-15

7.2 Manufacturers are identified by FSC numbers listed in table 7.2, "List of Suppliers". The code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1, H4-2, and their supplements.

7.3 Certain parts having 21793 (Dana) listed in the "FSC" column are specially-selected semiconductors. For some of these, standard commercial parts will serve as satisfactory replacements. These Dana parts are identified in table 7.1 along with the commercial equivalent.

Table 7.1

Semiconductor Type:	Equivalent:
018 Diode	Texas Instruments 1N4448

Table 7.2 - LIST OF SUPPLIERS

FSC	NAME	FSC	NAME
01295	TEXAS INSTRUMENTS, INC. (Components Group) DALLAS, TEXAS	07263	FAIRCHILD SEMICONDUCTOR (Division of Fairchild Camera & Instrument Corp.) MOUNTAIN VIEW, CALIFORNIA
04713	MOTOROLA, INC. (Semiconductor Products Division) PHOENIX, ARIZONA	09023	CORNELL-DUBILIER ELECTRONICS (Division Federal Pacific Electric Co.) SANFORD, NORTH CAROLINA
05397	UNION CARBIDE CORP. (Materials Systems Division) CLEVELAND, OHIO	11237	CTS KEENE, INC. PASO ROBLES, CALIFORNIA

Table 7.2 - LIST OF SUPPLIERS (continued)

FSC	NAME
21551	C-F ELECTRONICS, INC. VAN NUYS, CALIFORNIA
21793	DANA LABORATORIES, INC. IRVINE, CALIFORNIA
26625	MIAL USA, INC. NUTLEY, NEW JERSEY
27556	IMB ELECTRONIC PRODUCTS, INC. SANTA FE SPRINGS, CALIFORNIA
34553	AMPEREX/MEPCO-ELECTRA HAUPPAUGE, NEW YORK
50434	HEWLETT-PACKARD CO. (HP Associates) PALO ALTO, CALIFORNIA
56289	SPRAGUE ELECTRIC CO. (Pacific Division) LOS ANGELES, CALIFORNIA
71471	AEROVOX CORP. (Cinema Plant) MONCKS CORNER, SOUTH CAROLINA
71590	CENTRALAB ELECTRONICS (Division of Globe-Union, Inc.) MILWAUKEE, WISCONSIN
71785	TRW ELECTRONIC COMPONENTS (Cinch Division) ELK GROVE VILLAGE, ILLINOIS
72619	DIALIGHT CORP. (Sub of Digitronics Corp.) BROOKLYN, NEW YORK
73138	BECKMAN INSTRUMENTS, INC. (Helipot Division) FULLERTON, CALIFORNIA
73445	AMPEREX ELECTRONIC CORP. HICKSVILLE, LONG ISLAND, NEW YORK
75915	LITTELFUSE, INC. DES PLAINES, ILLINOIS
80031	MEPCO-ELECTRA MORRISTOWN, NEW JERSEY
80131	ELECTRONICS INDUSTRIES ASSOC. WASHINGTON, D.C.
81349	MILITARY SPECIFICATION
87730	UNITED MINERAL & CHEMICAL CORP. NEW YORK CITY, NEW YORK
89110	AMP, INC. (Capitron Division) ELIZABETHTOWN, PENNSYLVANIA
90201	MALLORY CAPACITOR CO. INDIANAPOLIS, INDIANA
91506	AUGAT, INC. ATTLEBORO, MASSACHUSETTS

400972 – DIGITAL MULTIMETER

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
A1	403407	HANDLE ASSY	21793	403407
A2	403860	MODULE ASSY	21793	403860
A3	403861	CASE ASSY	21793	403861
H1	453346	SHAFT, FRICTION, BAIL (2*)		
H2	453924	PANEL, SIDE INSERT (2*)		
H3	453926	LABEL, INPUT LIMIT (1*)		
H4	453934	COVER, DATA OUTPUT (1*)		
H5	453698	RUBBER CUSHION (1*)		
H6	610572	WASHER, NEOPRENE (2*)		
H7	610573	RING, RETAINING (2*)		
H8	610577	O-RING (2*)		
H9	610582	WASHER, MYLAR (4*)		
H10	615059	SCREW, PPH, 6-32 x 3/8 (4*)		
H11	617103	WASHER, FLAT #6 (4*)		
H12	610775	SCREW, DECORATIVE 3/8 LONG (4*)		
H13	615056	SCREW, 4-40 x 3/16 (2*)		
H14	730535	TAG, SERIAL (1*)		

*Quantity Required

403860 – Assy., MODULE – DMM

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
H1	920545	BAR KNOB (2*)		
H2	453933	ROD, POWER SWITCH (1*)		
H3	920747	KNOB, PUSHBUTTON (1*)		
H4	610174	NUT, 3/8 (2*)		
H5	610556	WASHER, MYLAR (1*)		
H6	615056	SCREW, 6-32 x 3/16 (5*)		
H7	610774	BUSHING, STRAIN RELIEF (1*)		
H8	617016	NUT, #4-40 S/S (2*)		
H9	617077	WASHER, LOCK #4 (2*)		
H10	617079	WASHER, LOCK #6 (5*)		
H11	453927	PANEL, FRONT STRUCTURE (1*)		
H12	453928	PANEL, FRONT OVERLAY (1*)		
H13	453931	PANEL, REAR (1*)		
J1	600770	BANANA JACK, RED		
J2	600772	BANANA JACK, BLACK		
J3	600771	BANANA JACK, WHITE		
S3	600778	POWER SWITCH, PUSHBUTTON	71590	PB1 Series

*Quantity Required

403863 – Assy., PCB, MAIN LOGIC

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
C1	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C2	120007	CAP	MYLAR	.22 MFD	600 V		27556	ZA1101
C3	130157	CAP	TRIMMER	2-10 PFD	500 V		80031	2222-801-96128
C4	120197	CAP	POLY	20 PFD	1000 V		87730	20-1000
C5	130109	CAP	TRIMMER	1-4 PFD			73445	2222-809-05001
C6	120198	CAP	POLY	12 PFD	500 V	20%	90201	SX412
C7	130055	CAP	CERAM	5-60 PFD		10%	73445	C010MA/60E
C8	120165	CAP	POLY	400 PFD	63 V	2.5%	26625	611
C9	130055	CAP	CERAM	5-60 PFD		10%	73445	C010MA/60E
C10	120142	CAP	POLY	FSV			21793	120142
C11	120162	CAP	POLY	.0044 MFD	63 V	2.5%	26625	611.2D
C12	120161	CAP	POLY	.047 MFD	63 V	2.5%	72619	N100
C13	121394	CAP	MYLAR	.15 MFD	100 V	10%	09023	WMF1P15
C14	101642	CAP	CERAM	150 PFD		10%	71471	SCD1X5F
C15	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C16	111148	CAP	ELECT	100 MFD	25 V		56289	TE1211
C17	111148	CAP	ELECT	100 MFD	25 V		56289	TE1211
C18	111148	CAP	ELECT	100 MFD	25 V		56289	TE1211
C19	120003	CAP	MYLAR	.1 MFD	100 V		09023	WMF1P1
C20	120216	CAP	MYLAR	.068 MFD	200 V		09023	WMF2S68
C21	120216	CAP	MYLAR	.068 MFD	200 V		09023	WMF2S68
C22	120211	CAP	MYLAR	.033 MFD	200 V			
C24	111148	CAP	ELECT	100 MFD	25 V		56289	TE1211
C25	120298	CAP	MYLAR	1.0 MFD	100 V	20%	73445	C281AH/A1M
C26	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C27	120323	CAP	MYLAR	2.7 MFD	100 V	10%	73445	C281AH/A2M7
C28	111148	CAP	ELECT	100 MFD	25 V		56289	TE1211
C32	110121	CAP	ELECT	2200 MFD	10 V		34553	ET222X010A03
C33	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C34	110112	CAP	ELECT	400 MFD	40 V		73445	C437ARG400
C35	110112	CAP	ELECT	400 MFD	40 V		73445	C437ARG400
C36	101174	CAP	CERAM	.001 MFD	500 V	10%	71471	SCD3X5F
C40	101174	CAP	CERAM	.001 MFD	500 V	10%	71471	SCD3X5F
C41	101644	CAP	CERAM	200 PFD	1000 V	20%	71471	GPDX5F201K
C42	101644	CAP	CERAM	200 PFD	1000 V	20%	71471	GPDX5F201K
C43	101175	CAP	CERAM	220 PFD	100 V	10%	71471	SCD1X5F
C44	101174	CAP	CERAM	.001 MFD	500 V	10%	71471	SCD3X5F
CR1	220022	DIODE	SILICO	ZENER			81349	1N965B
CR3	210058	DIODE	SILICO				81349	1N458
CR4	210058	DIODE	SILICO				81349	1N458
CR5	220007	DIODE	SILICO	ZENER			81349	1N751A

403863 – Assy., PCB, MAIN LOGIC *continued*

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
CR6	220015	DIODE SILICO ZENER	81349	1N967B
CR7	211083	DIODE SILICO 018	21793	211083
CR8	211083	DIODE SILICO 018	21793	211083
CR13	220007	DIODE SILICO ZENER	81349	1N751A
CR14	220004	DIODE SILICO ZENER	81349	1N961B
CR15	211083	DIODE SILICO 018	21793	211083
CR16	211083	DIODE SILICO 018	21793	211083
CR17	211083	DIODE SILICO 018	21793	211083
CR18	211083	DIODE SILICO 018	21793	211083
CR19	220045	DIODE ZENER	81349	1N827
CR20	211083	DIODE SILICO 018	21793	211083
CR21	220038	DIODE ZENER 8.2 V 5%	81349	1N959B
CR22	211083	DIODE SILICO 018	21793	211083
CR23	211083	DIODE SILICO 018	21793	211083
CR24	210004	DIODE SILICO	81349	1N4004
CR25	210004	DIODE SILICO	81349	1N4004
CR26	210004	DIODE SILICO	81349	1N4004
CR27	210004	DIODE SILICO	81349	1N4004
CR28	210004	DIODE SILICO	81349	1N4004
CR29	210004	DIODE SILICO	81349	1N4004
CR30	210004	DIODE SILICO	81349	1N4004
CR31	220012	DIODE SILICO ZENER	81349	1N958B
CR32	220012	DIODE SILICO ZENER	81349	1N958B
CR35	220029	DIODE ZENER	81349	1N759A
CR36	220038	DIODE ZENER 8.2 V 5%	81349	1N959B
CR37	220004	DIODE SILICO ZENER	81349	1N961B
F1†	920685	FUSE 1/4A 250 V 3AG	75915	312.250
H1	600525	HEATSINK, POWER (1*)		
H2	610234	TERMINAL (FSV) (2*)		
H3	615043	SCREW, PPH, 4-40 x 5/16 (1*)		
H4	617016	HEX NUT #4 RADIO (1*)		
H5	617077	LOCKWASHER #4 (1*)		
H6	920463	FUSE CLIP (2*)	91506	6008-324T
H7	410551	SHIELD, ROTARY SWITCH (1*)		
H8	453345	THERMAL EQUALIZING LINK (2*)		
J1	600777	CONN 18 PIN	89110	3-583486-3
J2	920734	CONN 14 PIN DUAL INLINE	71785	133-51-02-003
		*Quantity Required		

† For 230V Operation

F1	980754	FUSE 1/8A	

403863 – Assy., PCB, MAIN LOGIC *continued*

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
M11	230119	INTEGRATED CIRCUIT	07263	μA741
Q1	200112	TRANS MATCHED PAIR	21793	200112
Q2	200112	TRANS MATCHED PAIR	21793	200112
Q3	200088	TRANS SILICO PNP	80131	2N4248
Q4	200200	TRANS NPN	21793	200200
Q5	200088	TRANS SILICO PNP	80131	2N4248
Q6	200200	TRANS NPN	21793	200200
Q7	200200	TRANS NPN	21793	200200
Q8	200088	TRANS SILICO PNP	80131	2N4248
Q9	200200	TRANS NPN	21793	200200
Q10	200107	TRANS N-CHAN FIELD EFFECT	80131	2N4302
Q11	200107	TRANS N-CHAN FIELD EFFECT	80131	2N4302
Q12	200088	TRANS SILICO PNP	80131	2N4248
Q13	200200	TRANS NPN	21793	200200
Q14	200037	TRANS SILICO NPN	80131	2N3646
Q15	200200	TRANS NPN	21793	200200
Q16	200200	TRANS NPN	21793	200200
Q17	200199	TRANS DUAL	21793	200199
Q18	200200	TRANS NPN	21793	200200
Q19	200037	TRANS SILICO NPN	80131	2N3646
Q20	200200	TRANS NPN	21793	200200
Q21	200200	TRANS NPN	21793	200200
Q22	200044	TRANS SILICO NPN DUAL Matched Pr	21793	200044
Q23	200088	TRANS SILICO PNP	80131	2N4248
Q24	200044	TRANS SILICO NPN DUAL Matched Pr	21793	200044
Q25	200037	TRANS SILICO NPN	80131	2N3646
Q26	200037	TRANS SILICO NPN	80131	2N3646
Q27	200068	TRANS	80131	2N4250
Q28	200200	TRANS NPN	21793	200200
Q29	200107	TRANS N-CHAN FIELD EFFECT	80131	2N4302
Q30	200088	TRANS SILICO PNP	80131	2N4248
Q31	200037	TRANS SILICO NPN	80131	2N3646
Q33	200200	TRANS NPN	21793	200200
Q34	200166	TRANS NPN	04713	MPS-U05
Q36	200166	TRANS NPN	04713	MPS-U05
Q37	200200	TRANS NPN	21793	200200
Q39	200088	TRANS SILICO PNP	80131	2N4248
Q40	200166	TRANS NPN	04713	MPS-U05
Q46	200037	TRANS SILICO NPN	80131	2N3646
Q48	200037	TRANS SILICO NPN	80131	2N3646
Q49	200037	TRANS SILICO NPN	80131	2N3646

403863 – Assy., PCB, MAIN LOGIC *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
Q50	200200	TRANS		NPN			21793	200200
Q51	200200	TRANS		NPN			21793	200200
Q52	200200	TRANS		NPN			21793	200200
R1	010909	RES	METAL	100 OHM		.1%	81349	RN60C
R2	020561	RES	WW	1.03 OHM		1% 4.5 W	21551	M-30
R3	040193	POT	CERMET	100 OHM		20%	11237	360T101B
R4	000240	RES	CARBON	24 OHM		5% 1/4W	81349	RC07GF240J
R5	010916	RES	METAL	8.935 M		1%	81349	RN70C
R6	040250	POT	CERMET	50 K		20% 1/2W	73138	72PX
R7	010485	RES	METAL	872.5 K		1%	81349	RN65C
R8	040247	POT	CERMET	5 K		20% 1/2W	73138	72PX
R9	010486	RES	METAL	87.25 K		1%	81349	RN55C
R10	040187	POT	CERMET	500 OHM		20%	11237	360T501B
R11	010910	RES	METAL	8.725 K		1%	81349	RN55C
R12	040245	POT	CERMET	50 OHM		20% 1/2W	11237	360T500B
R13	010624	RES	METAL	976 OHM	T-0	1% 1/8W	81349	RN55D9760F
R14	010808	RES	METAL	10 K		.1%	81349	RN55C
R15	010530	RES	METAL	2 K	T-9	1%	81349	RN55E2001F
R16	000475	RES	CARBON	4.7 M		5% 1/4W	81349	RC07GF475J
R17	000206	RES	CARBON	20 M		5% 1/4W	81349	RC07GF206J
R18	010488	RES	METAL	12.4 K	T-9	1%	81349	RN55E
R19	040246	POT	CERMET	2 K		20% 1/2W	73138	72PX
R20	010492	RES	METAL	6.81 K	T-9	1%	81349	RN55E
R21	040187	POT	CERMET	500 OHM		20%	11237	360T501B
R22	010493	RES	METAL	1.74 K	T-9	1%	81349	RN55E
R23	000622	RES	CARBON	6.2 K		5% 1/4W	81349	RC07GF622J
R24	000223	RES	CARBON	22 K		5% 1/4W	81349	RC07GF223J
R25	000113	RES	CARBON	11 K		5% 1/4W	81349	RC07GF113J
R26	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R27	000511	RES	CARBON	510 OHM		5% 1/4W	81349	RC07GF511J
R28	040244	POT	CERMET	20 OHM		20% 1/2W	73138	72PX
R29	010495	RES	METAL	210 OHM		1%	81349	RN55E
R30	000472	RES	CARBON	4.7 K		5% 1/4W	81349	RC07GF472J
R31	010490	RES	METAL	10 K	T-9	1%	81349	RN55E
R32	010490	RES	METAL	10 K	T-9	1%	81349	RN55E
R33	010479	RES	METAL	1 M	T-2	.1%	81349	RN65C
R34	010479	RES	METAL	1 M	T-2	.1%	81349	RN65C
R35	010483	RES	METAL	52.63 K	T-2	.1%	81349	RN55C
R36	010482	RES	METAL	5.025 K	T-2	.1%	81349	RN55C
R37	010481	RES	METAL	500.2 OHM	T-2	.1%	81349	RN55C
R38	000133	RES	CARBON	13 K		5% 1/4W	81349	RC07GF133J

403863 – Assy., PCB, MAIN LOGIC *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R39	000273	RES	CARBON	27 K		5% 1/4W	81349	RC07GF273J
R40	000306	RES	CARBON	30 M		5% 1/4W	81349	RC07GF306J
R41	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R42	000106	RES	CARBON	10 M		5% 1/4W	81349	RC07GF106J
R43	000183	RES	CARBON	18 K		5% 1/4W	81349	RC07GF183J
R44	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R45	000121	RES	CARBON	120 OHM		5% 1/4W	81349	RC07GF121J
R46	000331	RES	CARBON	330 OHM		5% 1/4W	81349	RC07GF331J
R47	000622	RES	CARBON	6.2 K		5% 1/4W	81349	RC07GF622J
R48	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R49	010552	RES	METAL	422 OHM		1%	81349	RN55E
R50	040245	POT	CERMET	50 OHM		20%	11237	360T500B
R51	010530	RES	METAL	2 K	T-9	1%	81349	RN55E2001F
R52	000104	RES	CARBON	100 K		5% 1/4W	81349	RC07GF104J
R53	001762	RES	CARBON	1 M		5% 1 W		
R54	000514	RES	CARBON	510 K		5% 1/4W	81349	RC07GF514J
R55	000622	RES	CARBON	6.2 K		5% 1/4W	81349	RC07GF622J
R56	000204	RES	CARBON	200 K		5% 1/4W	81349	RC07GF204J
R57	000514	RES	CARBON	510 K		5% 1/4W	81349	RC07GF514J
R58	000624	RES	CARBON	620 K		5% 1/4W	81349	RC07GF624J
R59	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R60	000183	RES	CARBON	18 K		5% 1/4W	81349	RC07GF183J
R61	000222	RES	CARBON	2.2 K		5% 1/4W	81349	RC07GF222J
R62	010790	RES	METAL	36.5 K		1%	81349	RN55E
R63	600245	JUMPER						L-2007-1
R64	000222	RES	CARBON	2.2 K		5% 1/4W	81349	RC07GF222J
R65	000183	RES	CARBON	18 K		5% 1/4W	81349	RC07GF183J
R66	040231	POT	CERMET	5 K		10%	73138	89PR5K
R67	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R68	600245	JUMPER						L-2007-1
R69	010790	RES	METAL	36.5 K		1%	81349	RN55E
R70	000113	RES	CARBON	11 K		5% 1/4W	81349	RC07GF113J
R71	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R72	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R73	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R74	000513	RES	CARBON	51 K		5% 1/4W	81349	RC07GF513J
R75	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R76	000105	RES	CARBON	1 M		5% 1/4W	81349	RC07GF105J
R77	010490	RES	METAL	10 K	T-9	1%	81349	RN55E
R78	040187	POT	CERMET	500 OHM		20%	11237	360T501B
R79	010490	RES	METAL	10 K	T-9	1%	81349	RN55E
R80	000104	RES	CARBON	100 K		5% 1/4W	81349	RC07GF104J

403863 – Assy., PCB, MAIN LOGIC *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R81	000516	RES	CARBON	51 M		5% 1/4W	81349	RC07GF516J
R82	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R83	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R84	000513	RES	CARBON	51 K		5% 1/4W	81349	RC07GF513J
R85	040246	POT	CERMET	2 K		20% 1/2W	73138	72PX
R86	010911	RES	METAL	11.5 K		1%	81349	RN55E
R87	000107	RES	CARBON	100 M		5% 1/4W	81349	RC07GF107J
R88	000123	RES	CARBON	12 K		5% 1/4W	81349	RC07GF123J
R89	010555	RES	METAL	1.82 K	T-2	1%	81349	RN55C1821F
R90	000203	RES	CARBON	20 K		5% 1/4W	81349	RC07GF203J
R91	000105	RES	CARBON	1 M		5% 1/4W	81349	RC07GF105J
R92	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R93	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R94	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R95	000622	RES	CARBON	6.2 K		5% 1/4W	81349	RC07GF622J
R96	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R97	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R98	000273	RES	CARBON	27 K		5% 1/4W	81349	RC07GF273J
R100	000622	RES	CARBON	6.2 K		5% 1/4W	81349	RC07GF622J
R101	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R105	000472	RES	CARBON	4.7 K		5% 1/4W	81349	RC07GF472J
R108	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R110	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R111	000153	RES	CARBON	15 K		5% 1/4W	81349	RC07GF153J
R114	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R115	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R118	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R119	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R120	000153	RES	CARBON	15 K		5% 1/4W	81349	RC07GF153J
R121	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R122	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R123	000153	RES	CARBON	15 K		5% 1/4W	81349	RC07GF153J
R126	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R127	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R128	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R136	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R139	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R140	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R141	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R142	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R143	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J

403863 – Assy., PCB, MAIN LOGIC *continued*

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
R144	000103	RES CARBON 10 K 5% 1/4W	81349	RC07GF103J
R145	000273	RES CARBON 27 K 5% 1/4W	81349	RC07GF273J
S1	600523	SWITCH, ROTARY		
S2	600780	SWITCH, ROTARY		
T1	300080	TRANSFORMER, POWER		
U1	230132	INTEGRATED CIRCUIT	01295	SN7447N
U2	230132	INTEGRATED CIRCUIT	01295	SN7447N
U3	230132	INTEGRATED CIRCUIT	01295	SN7447N
U4	230037	INTEGRATED CIRCUIT	01295	SN7490N
U5	230037	INTEGRATED CIRCUIT	01295	SN7490N
U6	230037	INTEGRATED CIRCUIT	01295	SN7490N
U7	230072	INTEGRATED CIRCUIT	01295	SN7474N
U8	230028	INTEGRATED CIRCUIT	01295	SN7400N
U9	230064	INTEGRATED CIRCUIT	01295	SN7404N
U10	230037	INTEGRATED CIRCUIT	01295	SN7490N
U11	230064	INTEGRATED CIRCUIT	01295	SN7404N
U12	230028	INTEGRATED CIRCUIT	01295	SN7400N
W1	600245	JUMPER		L-2007-1
W2	600245	JUMPER		L-2007-1
W3	600245	JUMPER		L-2007-1
W4*	600245	JUMPER		L-2007-1
W5*	600245	JUMPER		L-2007-1
W6*	600245	JUMPER		L-2007-1

*W4 & W5 115V OPERATION ONLY
W6 for 230V OPERATION ONLY

403858 – Assy., PCB, DISPLAY

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
LED 1	210060	DIODE LED DISPLAY	50434	HP5082-7730
LED 2	210060	DIODE LED DISPLAY	50434	HP5082-7730
LED 3	210060	DIODE LED DISPLAY	50434	HP5082-7730
LED 4	210061	DIODE LED DISPLAY	50434	HP5082-7732
R1	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R2	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R3	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R4	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R5	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R6	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R7	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R8	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R9	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R10	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R11	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R12	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R13	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R14	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R15	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R16	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R17	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R18	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R19	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R20	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R21	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R22	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R23	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R24	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R25	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R26	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J
R27	000331	RES CARBON 330 OHM 5% 1/4W	81349	RC07GF331J

403859 – Assy., PCB, FUSE BOARD

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
CR1	210067	DIODE 3A SELECTED	21793	210067
CR2	210068	DIODE 3A SELECTED	21793	210068
CR3	210068	DIODE 3A SELECTED	21793	210068
CR4	210068	DIODE 3A SELECTED	21793	210068
CR5	210068	DIODE 3A SELECTED	21793	210068
CR6	210068	DIODE 3A SELECTED	21793	210068
CR7	210067	DIODE 3A SELECTED	21793	210067
CR8	210068	DIODE 3A SELECTED	21793	210068
CR9	210068	DIODE 3A SELECTED	21793	210068
CR10	210068	DIODE 3A SELECTED	21793	210068
CR11	210068	DIODE 3A SELECTED	21793	210068
CR12	210068	DIODE 3A SELECTED	21793	210068
F1	920488	FUSE 2A 250 V	75915	312002
H1	920463	FUSE CLIP (2*)		
R1	000103	RES CARBON 10 K 5% 1/4W	81349	RC07GF103J
R2	000102	RES CARBON 1 K 5% 1/4W	81349	RC07GF102J
R3	000103	RES CARBON 10 K 5% 1/4W	81349	RC07GF103J

*Quantity Required

400973 – Assy., DATA OUTPUT, Option 51

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
A1	403862	PCB ASSY, ISOLATED DATA OUTPUT	21793	403862
E1	453323	SHIELD		
H5	610221	SPACER, 1/4 x 1/8 LG (4*)		
H6	610278	SPACER, 4-40 x 3/4 LG (4*)		
H7	615044	SCREW, 4-40 x 3/8 LG (4*)		
H8	615046	SCREW, 4-40 x 1/2 LG (4*)		
H9	617077	WASHER, INT. LOCK (8*)		
P4	403338	CONNECTOR ASSY (1*)	21793	403338
H1	453029	CONNECTOR HOOD (1*)		
H2	600227	CONNECTOR 18 PIN (1*)	71785	251-18-30-160-50-36A-30
H3	615046	SCREW, 4-40 x 1/2 LG (2*)		
H4	617077	WASHER, LOCK #4 (2*)		
W201	403682	CABLE ASSY, FLAT (1*)	21793	403682
W101	500115	CABLE, 5 INCH		
P2†	600558	PLUG, FLAT 14P (1*)		3406-0000
P3††	600558	PLUG, FLAT 14P (1*)		3406-0000

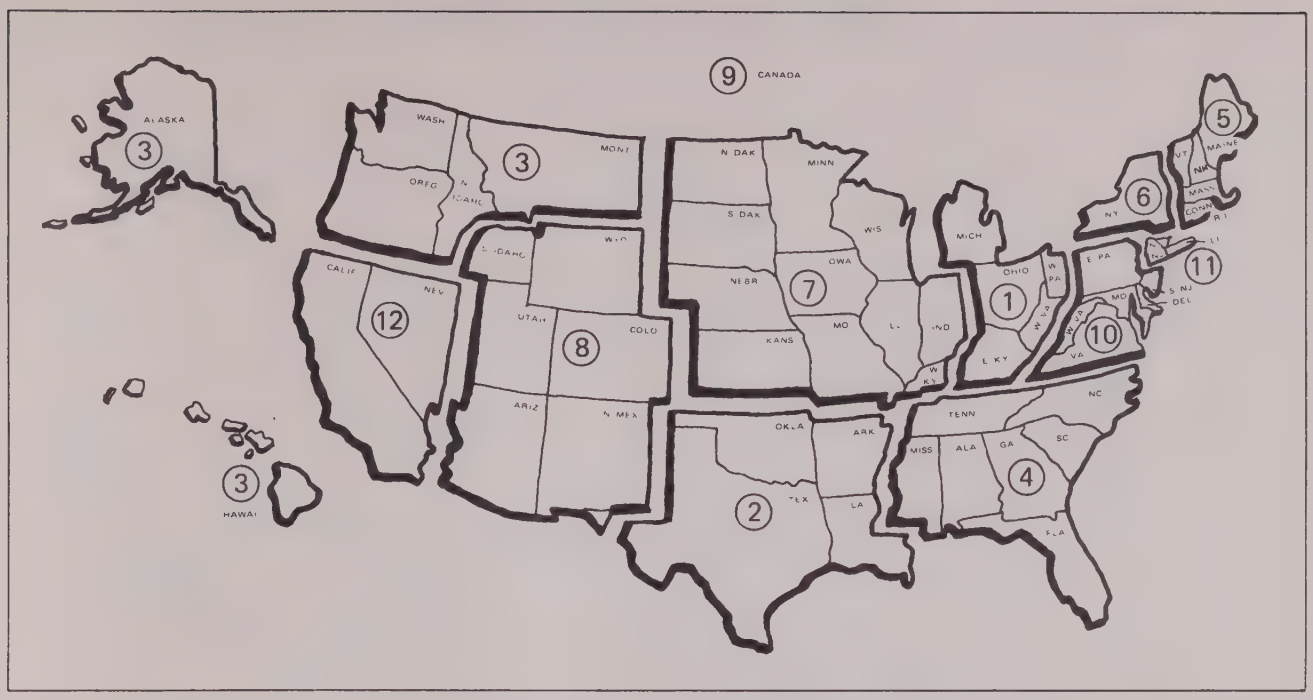
†J2 on Logic & Interconnection Board
††J3 on Data Output Board
*Quantity Required

403862 – Assy., PCB, DATA OUTPUT

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
C1	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C2	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C3	110127	CAP	TANTA	1 MFD	35 V	10%	05397	K10C25K
C4	100071	CAP	CERAM	3.3 PFD	1000 V	10%	56289	C030B102E3R3D
C5	100040	CAP	CERAM	200 PFD	1000 V	20%	56289	5GA-T20
CR1	211083	DIODE	SILICO		018		21793	211083
CR2	211083	DIODE	SILICO		018		21793	211083
CR3	211083	DIODE	SILICO		018		21793	211083
CR4	211083	DIODE	SILICO		018		21793	211083
CR5	211083	DIODE	SILICO		018		21793	211083
CR6	211083	DIODE	SILICO		018		21793	211083
J3	920734	CONN	DUAL INLINE	14P			71785	133-51-02-003
OCI-1	250005	ISOLATOR	OPTICALLY COUPLED		6-DIP			IL74
OCI-2	250005	ISOLATOR	OPTICALLY COUPLED		6-DIP			IL74
OCI-3	250005	ISOLATOR	OPTICALLY COUPLED		6-DIP			IL74
OCI-4	250005	ISOLATOR	OPTICALLY COUPLED		6-DIP			IL74
Q1	200037	TRANS	SILICO	NPN			80131	2N3646
Q2	200037	TRANS	SILICO	NPN			80131	2N3646
R1	000331	RES	CARBON	330 OHM		5% 1/4W	81349	RC07GF331J
R2	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R3	000331	RES	CARBON	330 OHM		5% 1/4W	81349	RC07GF331J
R4	000331	RES	CARBON	330 OHM		5% 1/4W	81349	RC07GF331J
R6	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R7	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R8	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R9	000331	RES	CARBON	330 OHM		5% 1/4W	81349	RC07GF331J
R10	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R11	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R13	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R14	000302	RES	CARBON	3 K		5% 1/4W	81349	RC07GF302J
R15	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R16	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R17	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R18	000302	RES	CARBON	3 K		5% 1/4W	81349	RC07GF302J
R19	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R20	000302	RES	CARBON	3 K		5% 1/4W	81349	RC07GF302J
R21	000302	RES	CARBON	3 K		5% 1/4W	81349	RC07GF302J

403862 – Assy., PCB, DATA OUTPUT *continued*

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
U1	230064	INTEGRATED CIRCUIT	01295	SN7404N
U2	230064	INTEGRATED CIRCUIT	01295	SN7404N
U3	230064	INTEGRATED CIRCUIT	01295	SN7404N
U4	230028	INTEGRATED CIRCUIT	01295	SN7400N
U5	230037	INTEGRATED CIRCUIT	01295	SN7490N
U6	230037	INTEGRATED CIRCUIT	01295	SN7490N
U7	230027	INTEGRATED CIRCUIT	01295	SN7490N
U8	230072	INTEGRATED CIRCUIT	01295	SN7474N
U9	230072	INTEGRATED CIRCUIT	01295	SN7474N
U10	230037	INTEGRATED CIRCUIT	01295	SN7490N
T1	403553	PULSE TRANSFORMER	21793	403553
T2	403553	PULSE TRANSFORMER	21793	403553
W2	600245	JUMPER		L-2007-1



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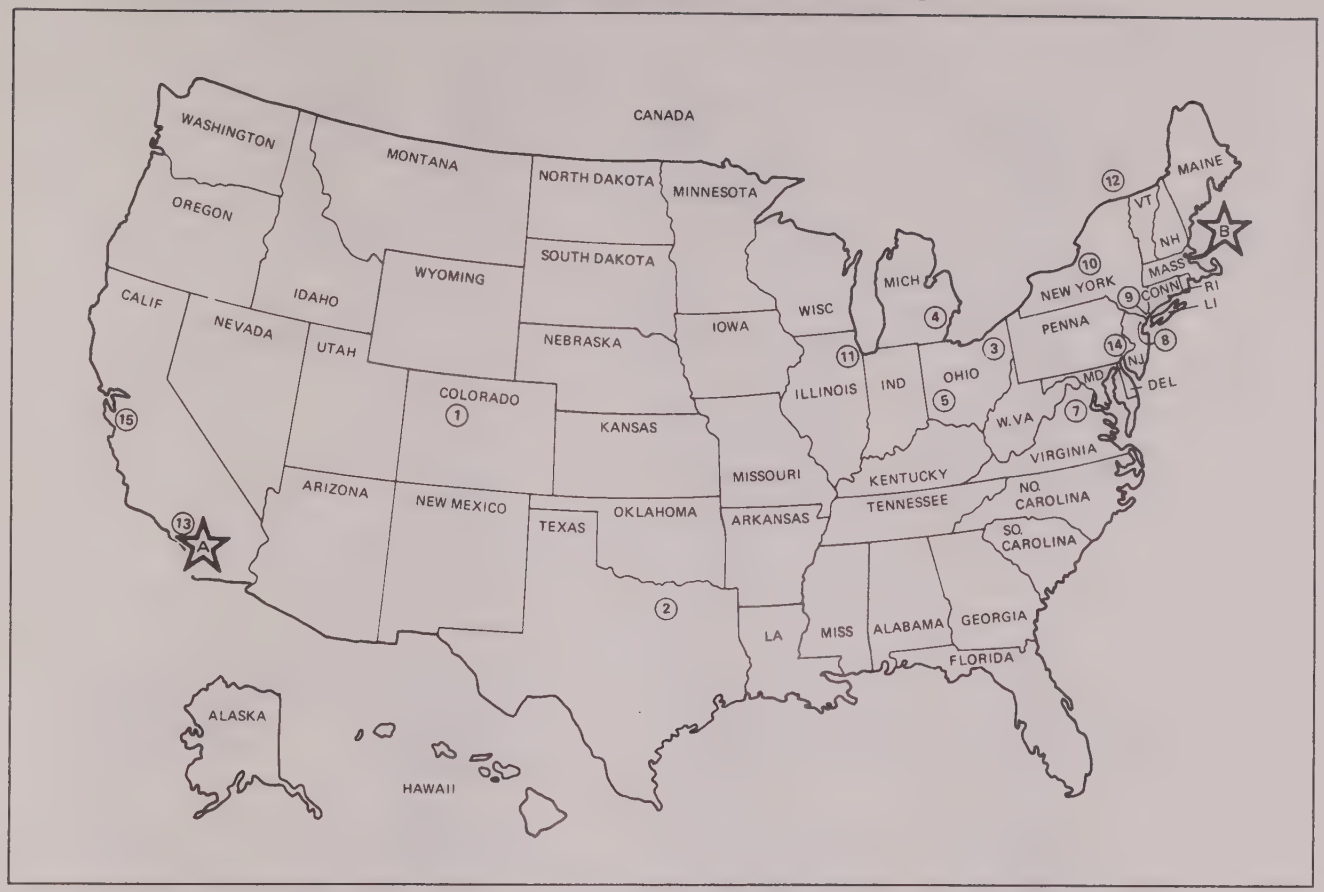

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